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Vol. 1. No. 2. June, 1944.

THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

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PUBLISHED QUARTERLY

By the Queensland Department of Agriculture and Stock, Brisbane

Issued by Direction of Hon. T. L. WILLIAMS,
Secretary for Agriculture and Stock.

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THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

VOL. 1. NO. 2.
JUNE, 1944

THE EFFECTS OF SEASON, STAGE OF GROWTH, AND SOIL TYPE ON THE CHEMICAL COMPOSITION OF GRASSES IN THE QUEENSLAND "WET BELT."

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SUMMARY.

1. The chemical composition of the principal grasses—Para, molasses, Guinea, sour and Russell River grasses—growing on alluvial soils in the tropical "wet belt" of Queensland was investigated. Only the leafy parts of the grasses, such as are eaten by cattle, were selected for analysis.

2. The dry matter content of Para, molasses and Guinea grasses is higher in long than in short grass; and is higher in the dry season than at the end of the wet season for both long and short Para and molasses grasses.

3. The crude protein content rises with the progress of the wet season and falls sharply during the dry spring months. There is no marked seasonal influence on the phosphate content, but in most cases the calcium content rises markedly during the dry period.

4. Long Para grass has a higher crude protein than short grass. Short molasses grass contains more phosphate than long, but is no higher in crude protein and calcium. Soil type affects the composition of Para grass.

5. A relationship is shown to exist between protein and phosphate for Para grass during the greater part of the year.

6. Possible deficiencies in the pasture revealed by the analyses are discussed and means of overcoming them are considered.

INTRODUCTION.

The Queensland "wet belt" is a relatively narrow tract of coastal country extending approximately from the Herbert River (lat. 18° 32′ S.) to the Daintree River (lat. 16° 22′ S.), a distance of about 160 miles. The coastal ranges of the Main Divide, lying between 10 and 50 miles from the coast, form the western boundary of the area. The region has a high rainfall and is watered by numerous swiftly-flowing rivers and creeks running from the ranges to the sea. The topography varies, being flat in some districts and hilly and broken in others.

The distribution of the flora of the region is governed largely by soil factors and under natural conditions the dominant type of vegetation is tropical rain-forest, commonly termed "scrub." This occupies the most fertile, deep soils, which are well supplied with moisture. Where the soil is shallower, or where for some other reason soil moisture conditions are less satisfactory, eucalypt forest or open plain country carrying native grasses predominates. The open forest formation occurs mainly on the least fertile soils, and these areas remain largely undeveloped, whereas the more fertile, cultivable scrub and plain country is now devoted mainly to the production of sugar cane.

For some years prior to the outbreak of war in 1939 attempts were being made in Queensland to expand the export trade in chilled beef, and particularly to ensure a continuity of supply throughout the year. In 1935 the late Mr. Brice Henry, who for many years had been engaged in raising cattle in North Queensland for the local market, conceived the idea of utilizing pastures in the wet belt for the purpose of fattening young stock for killing as "chillers." At that time Mr. Henry already had paddocks of Para grass (*Brachiaria purpurascens*) on his "Riversdale" property at Tully, and further areas of this and other grasses were quickly planted at "Riversdale." Plantings by other pioneers followed on various properties throughout the north-eastern coastal region. The exploratory work of these landholders soon established the fact that certain species of grasses were outstanding in the region for fattening cattle under a system of intensive grazing. Particularly good results were obtained from Para grass and this was used more extensively than any other species. However, it soon became apparent that, in order to develop the industry along sound lines, the collection of fundamental data upon the pastures was required. Accordingly, in co-operation with Mr. Henry, experiments were carried out at "Riversdale" to ascertain the relative merits of Para grass and other species then being used and to detect any major deficiencies in the chemical composition of the grasses. A series of pasture experiments was conducted between 1937 and 1940. The investigations reported

here were begun in 1939 and completed early in 1940. They deal with the chemical composition of the principal grass species in the Tully paddocks and the changes or differences in the composition of each species attributable to season, stage of growth, and soil type.

DESCRIPTION OF THE EXPERIMENTAL AREA.

Climate.

The climatic conditions of the Tully district are typical of those of the wet belt. The number of wet months in the year and the total precipitation are both sufficiently great to justify the use of the term "wet belt" in referring to the area, but there is a well-defined dry season of comparatively short duration. The average annual rainfall is about 150 inches, of which approximately 75 per cent. is recorded in the first six months of the year. The climate is, in short, a "monsoon climate," such as is typical of much of the humid tropics.

From January to July—the usual extent of the so-called wet season—the rainfall is high. Totals of over 30 inches are usual for each of the months of the "mid-wet" period—*i.e.*, February and March—and during this time the rainfall is characterized by intermittent torrential falls, when the surface run-off is considerable and flooding of rivers and creeks occurs. During April, May and June the rainfall is lower, though wet days are numerous; the surface run-off during this "late-wet" period is small, while the evaporation is low. As a consequence of these climatic conditions the soils are often waterlogged for several days. The cessation of the wet season is somewhat abrupt, July being usually a transition period heralding the approach of the dry season.

August, September and October are the dry months, when rainfall is light and sporadic and the skies are usually clear. Temperatures and evaporation during this period are moderate. The dry period is usually broken by storms in November, though the rainfall both in this month and in December is uncertain. Nevertheless, the rainfall usually is sufficient to promote new pasture growth, and these months mark the beginning of the period of increasing productivity.

The following meteorological data have been recorded at Innisfail, where climatic conditions are similar to those at Tully:—

Mean maximum and mean minimum temperatures for the year	83°F. and 65°F.
Mean maximum and mean minimum temperatures for the coldest month (July)	76°F. and 57°F.
Mean maximum and mean minimum temperatures for the hottest month (January)	88°F. and 72°F.
Relative humidity for the year (9 a.m. reading) ..	75% to 85%
Mean relative humidity for the year (9 a.m. reading)	81%

Soils.

The soils of the area on which the investigations were made are alluvial in character, and are of two distinct types, referred to here as the "scrub" soil and the "plain" soil. The scrub soil is so called because its native vegetation is a dense scrub or tropical rain-forest. The plain soil is the type belonging to a tract of flat country, between the Murray and the Tully Rivers, which is open and treeless and on which native grasses are practically the sole form of natural vegetation. These open areas are fairly extensive in places and seemingly are large flood plains. The scrub soil is a light-brown loam, friable and porous, and fairly deep. The plain soil is a dark-grey to black clay-loam, which is sticky when wet and hard and compact when dry. Drainage through this soil is impeded.

Mechanical analyses of samples of the scrub soil show that it consists mainly of fine sand (25 per cent.-30 per cent.), silt (22 per cent.-32 per cent.), and clay (26 per cent.-35 per cent.). It contains a moderate quantity of organic matter (4 per cent.-5 per cent.), fairly large quantities of nitrogen, and moderate amounts of lime and potash, but is deficient in phosphoric acid. The replaceable lime and available phosphate are both somewhat low, but the replaceable potash is apparently satisfactory. This type of soil is markedly acid. The range of values obtained from a number of analyses of the scrub soil, and an analysis of a sample of the plain soil, are set out in Table 1. It will be seen that the plain soil is apparently of lower average fertility than the scrub soil and is also more acid.

Table 1.

SOME ANALYTICAL DATA FOR THE SCRUB AND PLAIN SOILS.

——	Scrub Soil.	Plain Soil.
Nitrogen	0·26–0·32 per cent.	0·30 per cent.
CaO	0·20–0·30 per cent.	0·17 per cent.
K_2O	0·20–0·25 per cent.	0·19 per cent.
P_2O_5	0·12–0·14 per cent.	0·12 per cent.
Replaceable Ca	4·0–8·0 m.e. per cent.	4·0 m.e. per cent.
Replaceable K	0·5–1·0 m.e. per cent.	0·7 m.e. per cent.
Available P_2O_5 (Truog) ..	15–30 p.p.m.	30 p.p.m.
Fe_2O_3, Al_2O_3, MnO ..	22–28 per cent.	29 per cent.
SiO_2	58–65 per cent.	53 per cent.
pH	5·0–5·6	4·9

The plain country is flooded for a few days on at least one occasion each year. The scrub country is not so subject to flooding because of its slightly higher elevation, and only exceptionally high floods cover it to any extent; in any case the flood waters recede from it fairly quickly. Three of the experimental paddocks were situated on areas of scrub soil and the fourth on an area of plain soil.

Grasses.

The five species constituting practically the whole of the pasture complex on the experimental area comprised three cultivated perennials and two

adventitious indigenous perennials. The exotics were *Brachiaria purpurascens* Raddi (Para grass), *Melinis minutiflora* Beauv. (molasses grass) and *Panicum maximum* Jacq. (Guinea grass), which occupied 80 per cent., 12 per cent., and 2 per cent. respectively of the experimental paddocks. The indigenous species were *Paspalum conjugatum* Berg. (sour grass) and *Paspalum paniculatum* L. (Russell River grass), occupying 3 per cent. and 2 per cent. respectively of the paddocks.

It might seem that, because of the marked predominance of Para grass, this species was planted most extensively on the area. An examination of the history of the paddocks, however, revealed that in most of them the original mixture consisted of equal amounts of Para grass and molasses grass. Apparently climatic conditions are primarily responsible for the increase in the percentage of Para grass, for it has been observed that, under semi-saturated or fully saturated soil conditions, Para grass is much more aggressive than is molasses grass. During 1937-38 data on the rate of growth of Para grass were colllected by A. F. Skinner and R. F. Langdon in the course of investigations into the most suitable management practice for this grass. From their unpublished results these workers estimated that the rate of growth was roughly ten times as rapid at the flush in May and June as in November, when it was slowest. The storm rains of November, December and January caused a gradual improvement in the rate of growth, which increased fairly rapidly in February, March and April, remained constant during May, June and July, and then declined very rapidly during August and slowly during September and October to the minimum level of November. These observations suggest that there is some correlation between rainfall and rate of growth. A high correlation, however, is not to be expected, since much of the rain which falls during the wet season is ineffective, being lost by run-off and percolation. The water which is retained by the soil and subsequently utilized by the plant in its development—i.e., the effective rainfall—is a more significant factor. Actually it is found that growth is most prolific during the late-wet period, when fairly continuous light rain maintains the soil moisture at about field capacity.

Molasses grass flourishes in warm weather when provided with liberal soil moisture, but observations indicate that it at no time grows very rapidly. It is intolerant of waterlogged soil conditions and perishes or receives a severe check in positions where drainage is poor. On the other hand, in the dry season molasses grass seems to exceed Para grass in growth rate, and it is green and succulent-looking when Para grass is dry and unpalatable.

Guinea grass has been planted for observation purposes in a few small, scattered patches within the area. It consistently provides green, succulent feed, being apparently tolerant of both wet and dry conditions. Its large and relatively deep root system seems to enable the plant to draw upon a comparatively large amount of soil moisture in dry weather, but its growth rate is highest during periods of wet weather.

The two indigenous grasses are to be found mostly on the edges of the road through the paddocks and along pathways and pads and in other places

where the exotic grasses have been trampled out by the stock. Sour grass is eaten to some extent, but Russell River grass is avoided by cattle. Both of these grasses—and particularly sour grass—thrive best under wet conditions.

PURPOSE OF THE INVESTIGATIONS.

The purpose of the investigations discussed in this paper was to ascertain the nature and extent of any gross changes and differences which might occur in the chemical composition of each of the more important grass species growing on the alluvial soils at Tully. Information about each of the five grasses selected was sought along the following lines:—

1. Seasonal changes in chemical composition of "long" grass.
2. Seasonal changes in chemical composition of "short" grass.
3. Differences in chemical composition of "long" and "short" grass.
4. Differences in chemical composition of "long" and "short" grass between paddocks.

As Para grass was the most important species in the paddocks it was studied more intensively than the others.

TECHNIQUE.

Sampling Areas.

Four paddocks, each of approximately 60 acres, were set aside for the experiment. Paddocks 1, 2 and 3 were situated on scrub soil and Paddock 4 on plain soil. For the purpose of collecting Para grass samples, each paddock was marked off into four approximately equal areas, the subdivision being based mainly on obvious topographical differences where it was practicable to do so.

Time of Sampling.

The collection times were chosen so as to be representative of the four rainfall periods already discussed. They were usually as follows:—

1. Late December or early January ("pre-wet" period);
2. Late March or early April ("mid-wet" period);
3. Late June or early July ("late-wet" period);
4. Late September or early October ("mid-dry" period).

Type of Sample.

In order to get information concerning the composition of the grasses at different stages of growth, samples of long grass and short grass were collected

at each period. The heights adopted to distinguish the two stages are given below for each of the five grasses:—

	"long." ins.	"short." ins.
Para grass	> 24	< 12
Molasses grass	> 18	< 10
Guinea grass	> 24	< 12
Sour grass	> 10	< 6
Russell River grass	> 15	< 8

The distinctions as to height were not rigid, but were decided upon as the appropriate limits to serve as a guide to the collector and to ensure that two quite different stages of growth would be represented by the samples collected.

Collection Technique.

A collection technique was adopted which aimed at procuring only those parts of the grasses which are normally chosen by grazing cattle, since the chemical composition of pasturage not selectively sampled is of little significance where the bulk of the pasture is made up of a "stemmy" grass such as Para grass.

Close observations of the grazing habits of the stock had revealed that only the young, succulent leaf is selected by the animals from grasses such as Para grass and molasses grass. Old leaf and stem of these grasses are not eaten and the seedhead and stem of Guinea grass are likewise avoided. In order therefore, to obtain samples of the grasses which would represent the part actually ingested by stock the young, succulent leaf at the tips of the runners—or, in the case of short grass, bud or seedling leaf—was hand-plucked from Para and molasses grasses. From Guinea grass the leafy parts without stems or seedheads were selected. Similar judgement was used in sampling sour grass and Russell River grass.

Under grazing conditions Para grass may regenerate by various methods, viz., (*a*) by indeterminate elongation of its main stems or runners; (*b*) by the development of lateral buds on the stems; and (*c*) by the production of new tillers from the original crown. If the growing points at the ends of the main stems are not eaten off by stock the first method is dominant and may continue until checked by physiological limits. Where the stalks have been broken through below the growing point the development of lateral buds is stimulated. This occurs to the greatest extent under moist conditions, particularly where the nodes concerned make contact with the soil and take root. When rooting is well developed and the old stem begins to die the new leafy bud shoots elongate to form the main running stems of a new plant. The third method comes into prominence only where the main stems of a plant have been eaten or cut back severely to near the crown. This does not occur frequently with Para grass, except in the very young stages of growth. The samples of long material therefore consisted mainly of terminal leaf from old runners or from new runners developed from the crown or from lateral buds. Short material was derived mainly from newly developed lateral leaves.

Similar general conditions apply in the case of molasses grass, though here the growth is more erect, rooting at the nodes less common, and tillering from old crowns more prolific. In addition, seeding plays a more prominent part in the regeneration of this species. In the cases of Guinea grass, sour grass, and Russell River grass, long and short material would represent approximately semi-mature and young leaf respectively.

Number of Samples.

At each sampling, from each marked-off plot in each paddock a sample of long Para grass was collected by taking by hand over 100 pluckings throughout the area of each plot. Similarly, a sample of short Para grass was collected from each plot. Thus from each of the four paddocks four samples of young leaf of both long and short Para grass were collected. For the indicative tests of the other grasses a smaller number of samples of the leaf of each was plucked. The sampling aimed at for each collection period was as follows:—

1. Para grass—4 samples of long grass and 4 samples of short grass from each of the 4 paddocks.
2. Molasses grass—1 sample of long grass and 1 sample of short grass from each of the 4 paddocks.
3. Guinea grass—1 sample of long grass and 1 sample of short grass from each of 2 paddocks.
4. Sour grass and Russell River grass—1 sample of long grass and 1 sample of short grass from 1 padodck.

Because of the slow recovery of the grasses in the late-wet and mid-dry collection periods, it was not possible to obtain a complete series of samples at those times.

Treatment of Samples.

When practicable, the samples were weighed immediately after collection. Subsequently, they were sent to the Bureau of Tropical Agriculture at South Johnstone for drying and chemical analysis. A proximate analysis of the dried herbage of each sample was made, and, in addition, the calcium and phosphate contents were determined.

Grazing Practice.

Throughout the year the paddocks were grazed in rotation. The number of stock carried averaged 100 head. A three weeks' grazing period on each paddock was found to be satisfactory for most of the year. By such a routine each paddock was spelled for nine weeks, which, when rainfall was adequate, gave the grasses time to recover and produce a good stand of succulent leaf. An altered routine had to be adopted, however, in the latter part of the year, when the productivity of the grasses was low owing to particularly dry weather conditions and recovery of the paddocks was slow. To cope with the circumstances longer periods between grazings were allowed on some occasions, while eventually the number of head of stock was reduced.

RESULTS OF THE EXPERIMENTS.

Dry Matter Content of the Grasses.

Data were obtained on the dry matter content of two series of samples—one series taken at the late-wet period when productivity is high, and the other at the mid-dry period when productivity is low. Examination of the figures, which are shown in the appendix, reveals a considerable variation among samples taken during the same period. This is attributable largely to differences in topography, on account of which soil moisture variations were considerable; some samples were composed mostly of grass growing in depressions where drainage was not free. Such samples usually contained a high percentage of moisture in comparison with samples taken from more elevated sites. The data for the five grasses are summarized in Table 2.

Table 2.

DRY MATTER CONTENT OF THE GRASSES.

(Mean values; percentages of Green Weights.)

Para Grass.

—	Paddock 1.			Paddock 2.		
	Late-wet.	Mid-dry.	Mean.	Late-wet.	Mid-dry.	Mean.
Long ..	23·4	26·3	24·9	20·0	27·8	23·9
Short ..	21·5	22·3	21·9	18·4	23·0	20·7
Mean ..	22·4	24·3	23·4	19·2	25·4	22·3
	Long minus Short highly significant. Mid-dry minus late-wet highly significant.			Long minus Short significant. Mid-dry minus late-wet highly significant.		

No significant interaction between season and stage of growth, though suggestion of this in Paddock 1.

Molasses Grass.

——	Late-wet.	Mid-dry.	Mean.
Long	26·4	31·3	28·9
Short	23·9	28·1	26·0
Mean	25·1	29·7	27·4

Long minus Short significant.
Mid-dry minus late-wet highly significant.
No interaction between season and stage of growth.

Guinea Grass.

——	Late-wet.	Mid-dry.	Mean.
Long	29·9	33·6	31·8
Short	26·5	26·1	26·3
Mean	28·2	29·9	29·05

Long minus Short highly significant.
Seasonal difference and interaction not significant.

Sour Grass.

——	Late-wet.	Mid-dry.
Long	22·2	..
Short	23·2	23·7

Russell River Grass.

——	Late-wet.	Mid-dry.
Long	26·5	26·9
Short	24·8	25·0

In the case of Para grass, an analysis of the data indicates that both season and stage of growth have a significant effect upon the amount of dry matter. In the dry season the dry matter content of the grass is greater than at the end of the wet season, while the long grass contains more dry matter than the short at both of these periods. For Paddocks 1 and 2 the seasonal effect is highly significant in each case, while the effect of stage of growth is highly significant for Paddock 1 and significant for Paddock 2. No significant interaction is shown between season and stage of growth, although there is a suggestion of interaction in Paddock 1. The data from Paddocks 3 and 4 are inadequate to show interactions. In Paddock 3 (see appendix) the increase in dry weight for the mid-dry period over the late-wet period is considerably greater for long grass (only two replicates) than for short (four replicates), which suggests interaction between seasons and stage of growth as in Paddock 1. While the interaction has not proved significant in Paddocks 1 and 2, and cannot be proved in Paddocks 3 and 4 on account of insufficient data, there is a definite tendency for the difference between long and short grass in dry matter content to be more marked during the dry season than at the late-wet period. This accords with expectations, since during the dry season the grass tends to mature early, so that the long sample represents fairly mature grass while the short sample is still relatively young. During the late-wet period the long and the short samples would approximate more closely to the same stage of maturity.

With molasses grass the increase in dry matter content during the dry season is highly significant and is of the same order for both long and short samples. Long grass is also significantly higher in dry matter content than short in both periods.

The difference between long Guinea grass and short Guinea grass is highly significant. Because of the paucity of data no significance can be attached to the differences between seasons nor to interaction.

No important differences are manifested in the meagre data available for sour grass and Russell River grass.

Chemical Composition of the Grasses.

Para Grass.

The composition of Para grass shows definite seasonal changes which are of considerable importance. The crude protein content of both long and short grass rises steadily in the wet season and drops sharply in the three months of dry weather following the late-wet period (Table 3). For long grass the decrease is 3.9 per cent. and for short grass 3.4 per cent., both decreases being highly significant. In long grass the crude protein is significantly higher in the pre-wet period than in the dry season, but in short grass the difference is not significant. The inferior quality of the leaf in respect of crude protein after periods of dry weather is definitely established by these investigations. Wet weather, which greatly increases productivity, also improves the quality of the grass.

Table 3.

Showing the Analytical Data for the Oven-dry Material of Long and Short Para Grass at the Four Collection Periods (Mean Values).

Period.	Crude Protein.	N-free Extract.	Crude Fat.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5
				Long.			
A. Pre-wet	13·3	45·7	1·7	30·3	9·0	·528	·618
B. Mid-wet	14·8	45·0	1·6	29·9	8·6	·475	·559
C. Late-wet	15·1	*	*	*	9·5	·627	·596
D. Mid-dry	11·2	*	*	*	14·3	1·283	·532
Standard Error ..	±·470 A, B, C > D B, C > A	±·357	±·0453	±·115	±·485 D > A, B, C	±·0534 D > A, B, C	±·0254 A > D
F value ..	14·47 Highly significant	1·73 Not significant	< 1 Not significant	8·33 Not significant	30·07 Highly significant	49·35 Highly significant	2·24 Not significant
				Short.			
A. Pre-wet	11·8	46·4	1·8	30·0	10·0	·566	·649
B. Mid-wet	13·5	45·6	1·6	30·3	8·9	·475	·555
C. Late-wet	15·5	*	*	*	10·5	·675	·652
D. Mid-dry	12·1	*	*	*	12·7	1·047	·562
Standard Error ..	±·450 B, C > A, D C > B	±·542	±·0318 A > B	±·310	±·343 (A > B) C > B D > A, B, C	±·0231 A > B C > A, B D > A, B, C	±·0273 A, C > B (C > D)
F value ..	13·92 Highly significant	1·19 Not significant	12·10 Significant	< 1 Not significant	21·65 Highly significant	117·9 Highly significant	3·78 Not significant

Brackets, *e.g.*, (A > B), indicate that the difference is approaching significance at the 5 per cent. level.

* Not determined.

In the pre-wet period long grass is distinctly higher in protein than short, the mean difference being 1.5 per cent. (Table 4). The superiority of the long grass is maintained up to the mid-wet period, when the difference between the two stages is still about the same, although both have increased in protein content. Thereafter, the increase continues in both stages, but at a greater rate in the short grass, so that at the end of the wet season and in the mid-dry period the protein is about the same in both stages. The interaction between season and stage of growth is shown to be highly significant. On the mean protein values for the year, however, there is a highly significant difference of 0.39 per cent. in favour of long grass.

Table 4.

Showing the Differences between the Mean Values of the Percentages of the Various Constituents in Long and Short Para Grass at the Four Collection Periods, and the Mean Differences for all Analyses for the Year.

(Values for Long minus Short.)

Period.	Crude Protein.	N-free Extract.	Crude Fat.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.
A. Pre-wet	1·5	−0·8	−0·1	0·4	−0·9	−0·038	−0·031
B. Mid-wet	1·3	−0·6	0·0	−0·4	−0·3	−0·000	0·005
C. Late-wet	−0·4	*	*	*	−1·0	−0·048	−0·056
D. Mid-dry	−0·8	*	*	*	1·6	0·236	−0·030
Standard Error ..	±0·205	±0·348	±0·0402	±0·302	±0·298	±0·0447	±0·0292
	A, B > C, D				D > A, B, C	D > A, B, C	
F value ..	31·86	< 1	4·84	3·56	16·89	8·96	< 1
	Highly significant	Not significant	Not significant	Not significant	Highly significant	Highly significant	Not significant
Mean difference	0·39	−0·68	−0·07	−0·03	−0·13	0·038	−0·028
Standard Error ..	±0·102	±0·246	±0·0284	±0·214	±0·149	±0·0224	±0·015
	Highly significant	Not significant	Not significant	Not significant	Not significant	Not significant	Not significant

* Not determined.

Grass from Paddock 4—i.e., from plain soil—contains in most cases significantly less protein than grass from the three scrub-soil paddocks (Table 5). There are no significant differences between samples from the scrub soils. A highly significant interaction between paddocks and stage of growth was found for crude protein. Thus the difference in protein content between long and short grass is high and positive in Paddocks 2 and 3, and low and negative in Paddock 1. Paddock 2, in which the highest difference was obtained, was regarded as the best grazing paddock of the four; nevertheless, the practical significance of this interaction is difficult to assess.

Table 5.

SHOWING THE COMPOSITION OF LONG AND SHORT PARA GRASS FROM EACH OF THE FOUR PADDOCKS. (MEAN VALUES.)

Paddock No.	Crude Protein.	N-free Extract.	Crude Fat.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.
			LONG.				
1	13·2	44·4	1·6	30·2	10·5	·700	·526
2	14·7	45·0	1·6	29·9	10·4	·745	·635
3	14·3	45·2	1·9	29·1	10·4	·746	·622
4	12·3	46·7	1·6	31·2	10·2	·721	·523
Standard Error ..	±·470 2, 3 > 4	±·502 4 > 1	±·0640	±·162 1, 2 > 3 4 > 1, 2, 3	±·485	±·0534	±·0254 2, 3 > 1, 4
F value ..	5·35 Signi-ficant	3·70 Not signi-ficant	4·28 Not signi-ficant	28·24 Highly signi-ficant	< 1 Not signi-ficant	< 1 Not signi-ficant	5·64 Signi-ficant
			SHORT.				
1	13·5	45·5	1·6	29·8	10·5	·653	·601
2	13·5	46·4	1·8	30·0	10·7	·708	·593
3	13·9	45·5	1·8	29·1	10·6	·685	·669
4	12·0	46·8	1·7	31·6	10·2	·716	·555
Standard Error ..	±·450 (1, 2 > 4) 3 > 4	±·767	±·0449 (2 > 1)	±·438 4 > 1, 2, 3	±·343	±·0231	±·0273 3 > 4
F value ..	3·46 Not signi-ficant	< 1 Not signi-ficant	3·68 Not signi-ficant	5·72 Not signi-ficant	< 1 Not signi-ficant	1·50 Not signi-ficant	3·03 Not signi-ficant
			LONG MINUS SHORT.				
1	−0·3	−1·0	−·01	0·4	0·0	·047	−·075
2	1·2	−1·3	−·25	−0·1	−0·3	·038	·042
3	0·4	−0·3	−·09	−0·0	−0·2	·061	−·047
4	0·3	−0·1	−·10	−0·4	−0·1	·005	−·032
Standard Error ..	±·205 2 > 1, 3, 4 3 > 1	±·493	±·0568 3 > 2	±·427	±·298	±·0447	±·0292 2 > 1
F value ..	9·14 Highly signi-ficant	1·53 Not signi-ficant	6·34 Not signi-ficant	< 1 Not signi-ficant	< 1 Not signi-ficant	< 1 Not signi-ficant	2·94 Not signi-ficant

Brackets, *e.g.* (1 > 2), indicate that the difference is approaching significance at the 5 per cent. level.

Seasonal changes in the mineral content of Para grass are pronounced in the case of calcium, which is highest in the mid-dry period for both long and short grass. The increase in the dry season is large and highly significant. The phosphate, on the other hand, does not vary to any significant extent. The variations in the crude ash are strikingly parallel with those of calcium. At the mid-dry period the values for crude ash and calcium are higher for

long grass than for short grass, while at the other periods they are higher for short grass. These seasonal variations are highly significant; i.e., a highly significant interaction exists between seasons and stage of growth for crude ash and calcium. There is no significant difference in the mean values for the year of crude ash and calcium.

There is a similarity in the protein and phosphate variations between paddocks, mean phosphate being lowest in grass from Paddock 4. For long grass the phosphate is shown to be significantly higher in two of the scrub-soil paddocks—Paddocks 2 and 3—than in Paddock 4. A difference in crude fibre attributable to soil type is also indicated.

Molasses Grass.

A characteristic feature of the chemical composition of both long and short molasses grass is the significantly higher protein content at the end of the wet season than at any other period. The crude fibre increases significantly in the long grass from the pre-wet to the mid-wet period. For the pre-wet period the data indicate a higher crude fibre percentage in short grass, while for the mid-wet period they show a higher percentage in long grass. The seasonal variation in the differences is shown to be highly significant; i.e., a highly significant interaction exists between season and stage of growth for crude fibre. There is no significant difference in crude fibre content between long and short grass on the mean values for all analyses. The crude fat decreases in both long and short grass from the pre-wet to the mid-wet period and is of the same order for the two stages. The crude ash is significantly higher in the long grass on the mean values. The calcium and phosphate show no significant seasonal variations, except that in short grass the calcium is lower at the pre-wet period than at any other time. There is no significant difference between long and short grass in calcium content. In short grass phosphate is significantly greater than in long grass in the late-wet period as compared with the pre-wet and mid-wet, and also is greater on the mean values. A significant interaction between period and stage of growth exists for phosphate.

Table 6.

Showing the Analytical Data for the Oven-dry Material of Long and Short Molasses Grass at the Four Collection Periods (Mean Values).

Period.	Crude Protein.	N-free Extract.	Crude Fat.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.
				Long.			
A. Pre-wet	9·6	49·2	2·2	36·5	8·6	·399	·559
B. Mid-wet	9·7	47·5	1·6	33·7	7·6	·403	·614
C. Late-wet	13·1	*	*	*	7·3	·443	·575
D. Mid-dry	9·9	*	*	*	8·6	·424	·526
Standard Error ..	±·289 C > A, B, D	±·840	±·0354 A > B	±·643 B > A	±·631	±·0144	±·0548
F value ..	34·78 Highly significant	1·87 Not significant	169·0 Highly significant	12·21 Significant	1·06 Not significant	2·03 Not significant	< 1 Not significant

Table 6—continued.

SHOWING THE ANALYTICAL DATA FOR THE OVEN-DRY MATERIAL OF LONG AND SHORT MOLASSES GRASS AT THE FOUR COLLECTION PERIODS (MEAN VALUES)—*continued.*

Period.	Crude Protein.	N-free Extract.	Crude Fat.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.
				SHORT.			
A. Pre-wet	8·7	49·3	2·1	31·6	8·3	·360	·570
B. Mid-wet	9·9	49·6	1·6	32·0	7·1	·403	·608
C. Late-wet	13·1	*	*	*	7·6	·439	·746
D. Mid-dry	10·7	*	..*	*	8·3	·443	·583
Standard Error ..	±·640 C > A, B (C > D)	±1·131	±·110 (A > B)	±·347	±·407	±·0118 B, C, D > A (D > B)	±·0561
F value ..	8·43 Highly significant	< 1 Not significant	12·52 Significant	< 1 Not Significant	2·32 Not significant	10·67 Highly significant	2·09 Not significant

Brackets, *e.g.* (A > B), indicate that the difference is approaching significance at the 5 per cent. level.

* Not determined.

Table 7.

SHOWING THE DIFFERENCES BETWEEN THE MEAN VALUES OF THE PERCENTAGES OF THE VARIOUS CONSTITUENTS IN LONG AND SHORT MOLASSES GRASS AT THE FOUR COLLECTION PERIODS, AND THE MEAN DIFFERENCES FOR ALL ANALYSES FOR THE YEAR. (VALUES FOR LONG MINUS SHORT.)

Period.	Crude Protein.	N-free Extract.	Crude Fat.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.
A. Pre-wet	1·0	−0·1	0·1	−1·2	0·23	0·039	−0·011
B. Mid-wet	−0·2	−2·0	0·0	1·7	0·53	−0·001	0·006
C. Late-wet	0·1	*	*	*	−0·28	0·005	−0·171
D. Mid-dry	−0·8	*	*	*	0·25	−0·019	−0·057
Standard Error ..	±0·707	±0·561	±0·126	±0·564 B > A	±0·297	±0·0134 A > D	±0·0357 A, B > C
F. Value ..	1·00 Not significant	5·73 Not significant	< 1 Not significant	12·56 Highly significant	1·26 Not significant	3·26 Not significant	5·00 Significant
Mean Difference	0·03	−1·08	0·05	0·26	0·53	0·001	−0·058
Standard Error ..	±0·354 Not significant	±0·397 Not significant	±0·089 Not significant	±0·399 Not significant	±0·149 Significant	±0·0067 Not significant	±0·0178 Significant

* Not determined.

Table 8.

SHOWING THE COMPOSITION OF LONG AND SHORT MOLASSES GRASS FROM EACH OF THE FOUR PADDOCKS. (MEAN VALUES.)

Paddock No.	Crude Protein.	N-free Extract.	Crude Fat.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.
			LONG.				
1	10·3	48·2	2·2	31·9	8·2	·452	·523
2	10·4	48·8	1·9	33·2	7·4	·417	·516
3	10·7	47·5	1·7	32·3	8·3	·385	·674
4	11·0	49·0	1·8	31·0	8·2	·415	·562
Standard Error ..	±·289	±1·188	±·050 1 > 2, 3, 4	±·909	±·631	±·0483 1 > 3	±·0548
F value ..	1·05 Not significant	< 1 Not significant	18·6 Significant	1·05 Not significant	< 1 Not significant	3·63 Not significant	1·78 Not significant
			SHORT.				
1	10·1	49·1	2·0	32·6	8·0	·456	·509
2	10·8	48·9	2·2	32·7	7·8	·407	·569
3	11·4	48·7	1·6	31·3	7·6	·371	·791
4	9·9	51·1	1·7	30·7	8·0	·411	·639
Standard Error ..	±·640	±1·599	±·156	±·496	±·407	±·0118 1 > 2, 3, 4 (4 > 3)	±·0561 3 > 1, 2
F value ..	1·13 Not significant	< 1 Not significant	2·55 Not significant	3·98 Not significant	< 1 Not significant	8·67 Highly significant	4·69 Significant
			LONG MINUS SHORT.				
1	0·2	−0·9	·25	−0·8	·23	−·003	·014
2	−0·5	−0·1	−·25	0·6	−·40	·010	−·053
3	−0·7	−1·2	·1	1·0	·65	·014	−·117
4	1·1	−2·1	·1	0·3	·25	·004	−·077
Standard Error ..	±·707	±·794	±·178	±·797	±·297 3 > 2	±·0134	±·0357 1 > 3
F value ..	1·27 Not significant	1·08 Not significant	1·42 Not significant	< 1 Not significant	2·13 Not significant	< 1 Not significant	2·35 Not significant

Brackets, *e.g.* (1 > 2), indicate that the difference is approaching significance at the 5 per cent. level.

No significant differences in composition due to soil type are shown, though there is a difference as between paddocks on the scrub soil, the short grass from Paddock 3 being significantly higher in phosphate and lower in calcium than grass from Paddock 1. There is no significant interaction between paddocks and stage of growth.

The analytical data for molasses grass are summarized in Tables 6, 7 and 8.

Guinea Grass.

The data available for Guinea grass, which are summarized in Table 9, are not adequate for statistical analysis, but the indications are that the protein is low, particularly in the long grass, during the dry season, after which it rises fairly rapidly and is high in both long and short grass at the end of the

Table 9.

Showing the Analytical Data for the Oven-dry Material of Long and Short Guinea Grass at the Four Collection Periods. (Mean Values.)

—	Crude Protein.	N-free Extract.	Crude Fat.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.
				Long.			
A. Pre-wet	8·5	46·2	1·2	34·2	10·0	·523	·450
B. Mid-wet	11·5	42·8	1·6	35·0	9·2	·575	·387
C. Late-wet	14·1	*	*	*	11·7	·863	·488
D. Mid-dry	8·5	*	*	*	14·0	·990	·382
				Short.			
A. Pre-wet	9·8	45·1	1·3	34·7	9·2	·573	·439
B. Mid-wet	10·8	44·1	1·3	35·3	8·6	·584	·405
C. Late-wet	14·5	*	*	*	10·3	·688	·553
D. Mid-dry	11·3	*	*	*	11·1	·959	·526

* Not determined.

Table 10.

Showing the Analytical Data for the Oven-dry Material of Long and Short Sour Grass at the Four Collection Periods.

—	Crude Protein.	N-free Extract.	Crude Fat.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.
				Long.			
A. Pre-wet	8·4	46·9	0·6	34·9	9·2	·411	·469
B. Mid-wet	12·5	45·7	1·7	31·1	9·0	·440	·606
C. Late-wet	11·3	*	*	*	11·1	·536	·585
D. Mid-dry			Not sampled				
				Short.			
A. Pre-wet	8·7	46·6	0·8	34·4	9·5	·363	·478
B. Mid-wet	13·0	45·6	1·5	29·0	10·9	·449	·527
C. Late-wet	11·1	*	*	*	12·1	·554	·566
D. Mid-dry	8·8	*	*	*	13·7	·804	·427

* Not determined.

wet season. The calcium content also appears to vary greatly, being particularly high in the mid-dry period but much lower in the pre-wet, with little difference between long and short grass at these periods. The phosphate content, on the other hand, probably decreases in dry weather and is mostly higher in the short grass. If significant, these changes in the mineral content of Guinea grass resemble those of Para grass.

Sour Grass and Russell River Grass.

The meagre data obtained for sour grass and Russell River grass are summarized in Tables 10 and 11. They are suggestive only, but indicate that the protein contents of the grasses are highest at the mid-wet period, and that the calcium content tends to rise in the dry period and the phosphate content to fall.

Table 11.

SHOWING THE ANALYTICAL DATA FOR THE OVEN-DRY MATERIAL OF LONG AND SHORT RUSSELL RIVER GRASS AT THE FOUR COLLECTION PERIODS.

—	Crude Protein.	N-free Extract.	Crude Fat.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.
			LONG.				
A. Pre-wet	7·9	45·5	1·4	36·1	9·1	·474	·341
B. Mid-wet	11·5	46·4	1·6	33·1	7·4	·387	·425
C. Late-wet	11·4	*	*	*	9·1	·392	·410
D. Mid-dry	7·6	*	*	*	11·8	·665	·239
			SHORT.				
A. Pre-wet	7·6	45·1	1·1	37·9	8·3	·378	·334
B. Mid-wet	13·4	46·4	2·0	29·5	8·7	·436	·449
C. Late-wet	12·5	*	*	*	10·7	·360	·460
D. Mid-dry	11·5	*	*	*	10·8	·635	·310

* Not determined.

GENERAL DISCUSSION OF RESULTS.

Effect of Season.

The protein content in most cases rises with the advance of the wet season and falls sharply upon its cessation. Except for a sharp rise in the calcium content in the dry season, there is no very marked seasonal influence upon the mineral content of the various grasses. Examination of the appropriate figures in the several tables of chemical composition shows that there is a general tendency towards a high calcium content in dry weather and a low calcium content during the wet season for all the grasses except molasses grass, in which the calcium content shows no relationship to rainfall.

Effect of Stage of Growth.

The data show that, for the greater part of the year, long Para grass contains more crude protein than does short grass. The difference assumes

importance during the summer and autumn, which are the periods when rate of growth is high. There are no important differences between the two stages of growth in Para grass in respect to other constituents. The analytical data support the observation of Seddon and Mulhearn (1938) that stock grazing on the Para grass pastures at Tully gained weight more rapidly when depastured on paddocks carrying a stand of tall grass (18-24 inches) than when on paddocks of short grass (6-8 inches). A graphical representation of the relationships between rainfall and protein and mineral composition of long and short Para grass is given in Figure 1.

In the other species it was found that the short grass is usually of higher protein content than the long grass, except in the case of molasses grass, in which no important difference in chemical composition between the two stages of growth was found. With these grasses, maturity factors were probably responsible for the difference in composition; whereas with Para grass the maturity factor operated only in the dry season, when the long grass represented mature grass which probably was not grazed by the stock because of its dry, unpalatable condition, due perhaps to lignification, as is suggested by the relatively high content of dry matter and the low protein content.

Effect of Soil Type.

Soil type has a significant effect upon the composition of Para grass, but not upon that of molasses grass. The scrub soil has been shown to produce a better quality Para grass than the plain soil. A significantly higher quantity of protein, a lesser quantity of fibre, and a slightly higher content of mineral matter are present in the leaf from the scrub soil. The indications from field observations are that the grass on the scrub soil has greater recuperative powers.

Nutritive Value of the Grasses.

The following discussion of the feeding value of the grasses is based upon the data recorded. Whilst chemical analysis is inadequate to express precisely the nutritive value of a grass, it is considered a sufficiently sound basis upon which the relative feeding values of grasses grown under the same conditions of soil and climate may be assessed.

Of the five grasses, Para grass contains the highest average percentage of crude protein at all periods of the year. The figures are about 14 for the scrub soil and 12 for the plain soil, with a general average during the wet season of 15 and during the dry season of 11.5. The coefficient of digestibility of the crude protein in the material eaten by the cattle is hardly likely to be lower than 60 (Harrison (1942) has reported it to be 67 in 8-weeks old Para grass), so that the digestible crude protein should not fall lower than about 7 per cent. Para grass pasture, then, may be regarded as having an adequate protein content throughout the year. Similarly, molasses grass, which has a crude protein content of between 10 per cent. and 11 per cent. throughout the year, may be accepted as satisfactory as a supplier of protein. Moreover, the fibre content of these two grasses is not high, so that, provided the stock always have access

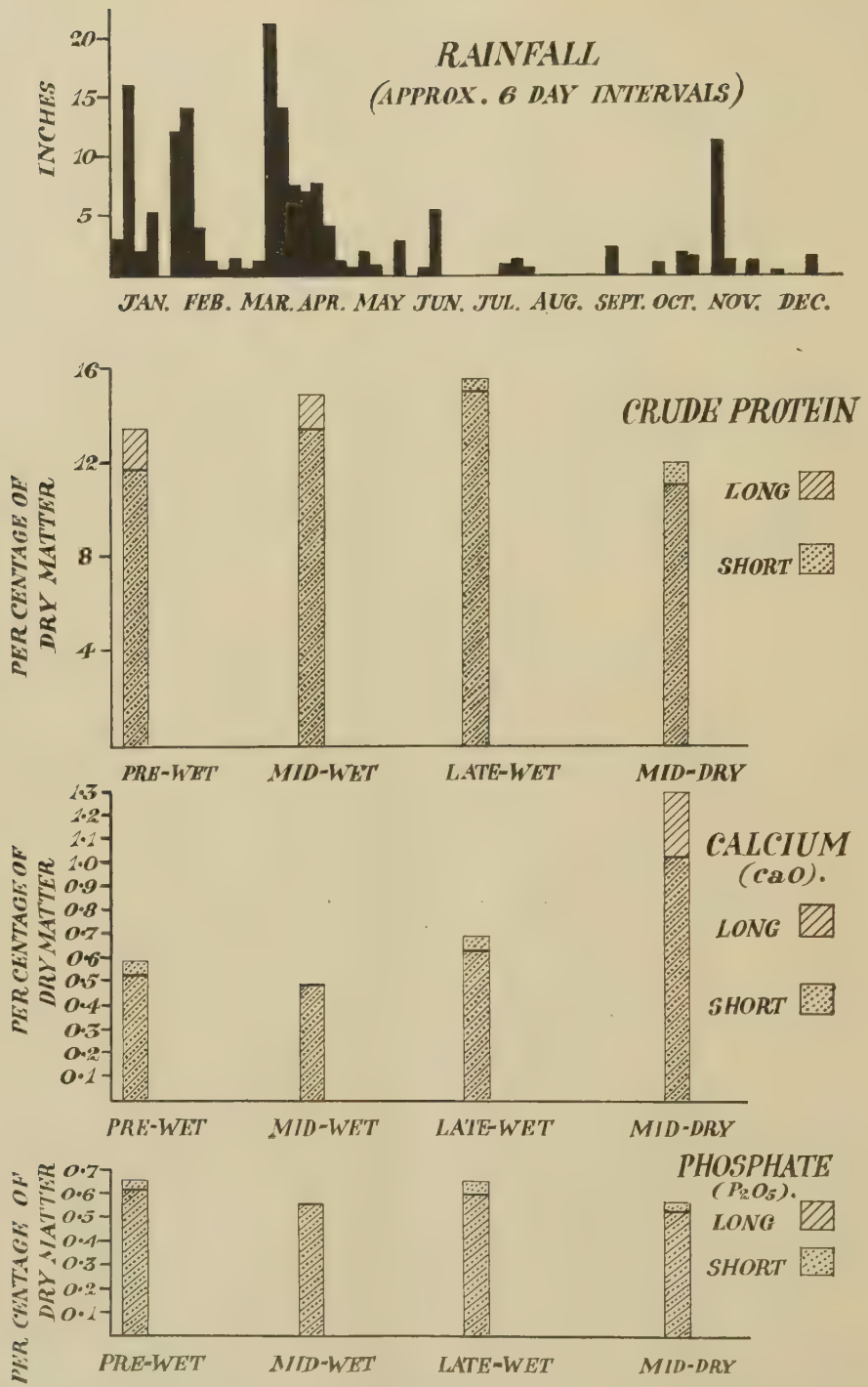

Fig. 1.

Showing the Seasonal Fluctuations in the Percentages of Crude Protein, Calcium, and Phosphate in Long and Short Para Grass, and their Relationship to the Rainfall.

to succulent leaf, the intake of the growth and energy-producing constituents should be adequate.

Guinea, sour and Russell River grasses probably have an adequate crude protein content during the wet season, but the analyses indicate that in dry periods the fibre content of these grasses is fairly high and the protein content correspondingly low, so that at these times the protein intake from them may not be sufficient for fattening purposes.

It is of interest to consider the mineral analyses of the Tully grasses on the basis of the conventional standard of chemical analyses of good European pastures. The conventional standard for phosphate for maintenance requirements is approximately 0.50 per cent. P_2O_5 in the dry matter content. Maynard (1937) considers that a P_2O_5 content of at least 0.70 per cent. is required during periods of maximum demand, e.g. the growth period. The conventional standard for calcium is similarly about 0.50 per cent. CaO for maintenance purposes.

Judged on these standards, Para grass contains an adequate quantity of the two minerals for maintenance requirements. The calcium content is roughly 0.5 per cent., and the phosphate content 0.6 per cent., except in the dry season, when the percentage of calcium is more than doubled. Though satisfactory for maintenance purposes, it is questionable whether the quantities are adequate for growth requirements, particularly in regard to phosphate. However, provided the animals eat enough grass, adequate sunshine—by virtue of which ample Vitamin D is supplied—would ensure an efficient utilization of the minerals, and the requirements for growth might be met.

Molasses grass appears to be somewhat deficient in calcium, with an average content of approximately 0·4 per cent. The phosphate content is satisfactory at approximately 0·6 per cent. Guinea grass is deficient in phosphate, which averages approximately 0·4 per cent. for the year. The calcium content is comparatively high at about 0·6 per cent. Sour grass is deficient in calcium, but its phosphate content is fairly satisfactory. Russell River grass is deficient in both minerals.

The ratio of protein to phosphate in an intensively grazed pasture is held by some workers to be of nutritional significance. It has been stated that in a good pasture the ratio of N to P_2O_5 is most frequently found to be between 3 : 1 and 5 : 1. The analyses of the Tully grasses show that the ratios for the several species vary. For example, for Para grass the ratio is generally between 3 : 1 and 4 : 1; for molasses grass 2·5 : 1 and 3 : 1; and for Guinea grass 3 : 1 and 4·8 : 1. For Para grass and Guinea grass the ratio is widest in the wet season, due mainly to an increased crude protein content, and narrowest in the dry season, when the crude protein percentage is not so high. No clear seasonal effect on the ratio for molasses grass was found.

Many workers have found that a positive and significant correlation exists between the nitrogen and the phosphate in an intensively grazed pasture.

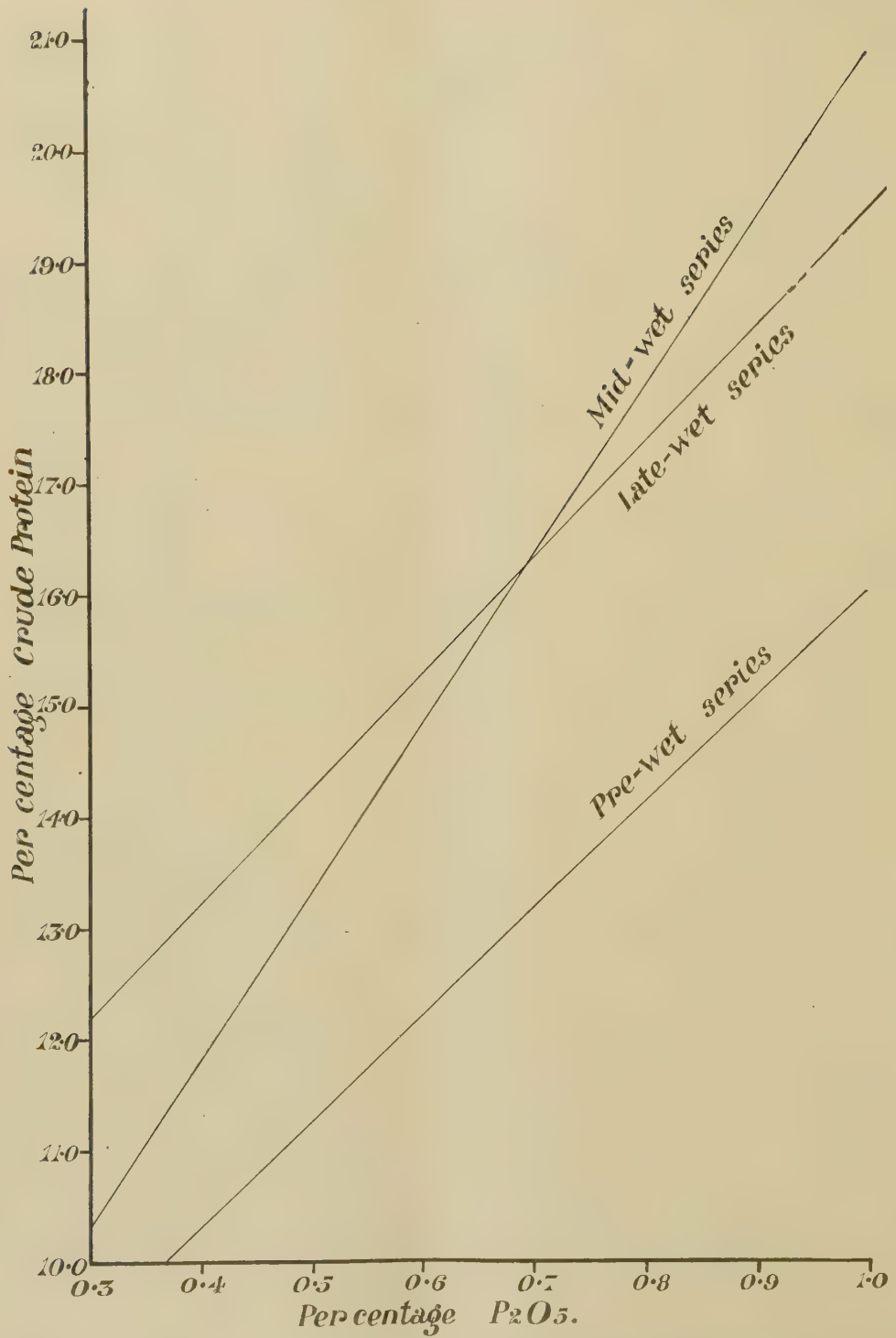

Fig. 2.

Showing the Regression Lines for Protein on Phosphate for the Pre-wet, Mid-wet, and Late-wet Series of Samples.

An analysis of the data for Para grass confirms the existence of such a correlation in all but the dry season. For each of the pre-wet, mid-wet, and late-wet series of samples the correlation is shown to be positive and highly significant. The absence of a correlation in the dry season can probably be explained by the fact that much of the grass composing the samples for that period had reached a mature state and therefore could not be placed in the category of an intensively grazed pasture.

Table 12 summarizes the correlation coefficients and the regression coefficients for protein on phosphate for each series of samples of Para grass, and Figure 1 shows the regression lines for protein on phosphate for the pre-wet, mid-wet, and late-wet series of samples.

Table 12.

Showing the Correlation and Regression Coefficients of Protein (y) and Phosphate (x) for each Series of Samples of Para Grass.

—	Pre-wet Series.	Mid-wet Series.	Late-wet Series.	Mid-dry Series.
Correlation Coefficient (r_{xy})	0·637	0·717	0·658	0·178
Regression Coefficient (b_{yx})	9·5	14·96	10·34	..
Degrees of Freedom	30	30	22	26
	Highly significant	Highly significant	Highly significant	Not significant

Practical Considerations.

Considered from the aspect of chemical composition, the general superiority of Para grass over its associates in the Tully pastures is outstanding. Its protein content is uniformly high, its crude fibre content is at no time high, and its mineral content, so far as calcium and phosphate are concerned, appears satisfactory for maintenance purposes. As this grass is agronomically satisfactory for pasture purposes its use in preference to the other grasses in localities similar to those of the experimental area is indicated.

There is a suggestion in the data obtained that the phosphate content of the pasturage may be inadequate at times, especially during drought periods; for the requirements of growing stock both now and, more particularly, in future years it would be desirable to increase it. The risk of phosphate becoming a limiting factor can be avoided either by fertilizing the soil with phosphatic fertilizers or by administering phosphate directly to the stock in the form of phosphatic licks. The latter method would correct any deficiency at a relatively low cost. Furthermore, because only a small proportion of the phosphate ingested in this way is retained and utilized by the animal, there must be an appreciable quantity of the mineral voided in the excreta. Most of this unabsorbed phosphate would eventually enter the soil complex and by enhancing fertility would enrich the pastures. The cumulative effect of the phosphates thus added to the soil would gradually effect much the same result on soil fertility as would the direct application of phosphatic fertilizers to the soil.

However, direct fertilizing with the object of facilitating the establishment and promoting the development of leguminous plants should be given every consideration. Furthermore, the effect of the application of phosphatic fertilizers in lessening transpiration rate of pasture plants might be capable of useful application at Tully, for Para grass has been observed to wilt and decline seriously during spells of dry weather in September, October, and November.

ACKNOWLEDGEMENTS.

Grateful acknowledgment is made of the public-spiritedness of the late Mr. Brice Henry, who set aside for use by the Department of Agriculture and Stock the grassland paddocks on which the experiments were conducted and who actively and enthusiastically co-operated in the work.

Mr. P. B. McGovern, of the Department's biometrical staff, is responsible for the statistical analysis of the chemical data. Dr. L. G. Miles, who was formerly on the staff of the Bureau of Tropical Agriculture, advised on matters concerning correlation coefficients. Mr. J. Hart helped to collect the samples and assisted in the laboratory during the course of the experiment. The collaboration of the Director of the Animal Health Station, Oonoonba (Mr. C. R. Mulhearn) was appreciated.

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APPENDIX.

ANALYSIS OF INDIVIDUAL GRASS SAMPLES.

1. Para Grass.

(a) Pre-wet Series.

Stage of Growth.	Paddock No.	Division No.	Analysis of Water-free Material.						
			Crude Protein.	Crude Fat.	N-free Extract.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.
Long ..	1	1	11·2	1·4	45·4	32·7	9·3	·498	·388
,, ..	1	2	14·7	1·5	43·3	30·0	10·5	·638	·500
,, ..	1	3	12·1	1·5	46·3	29·1	11·0	·674	·533
,, ..	1	4	12·0	1·8	46·0	29·3	10·9	·758	·620
Short ..	1	1	11·5	1·7	43·6	29·7	13·5	·619	·580
,, ..	1	2	11·2	1·6	47·2	29·6	10·4	·527	·637
,, ..	1	3	10·9	1·5	49·0	29·6	9·0	·556	·581
,, ..	1	4	14·4	2·0	44·2	28·2	11·2	·497	·917
Long ..	2	1	13·3	1·5	48·3	29·3	7·6	·385	·597
,, ..	2	2	15·2	1·4	46·4	29·8	7·2	·341	·618
,, ..	2	3	13·0	1·5	45·1	32·2	8·2	·522	·684
,, ..	2	4	15·7	1·8	41·7	29·9	10·9	·525	·787
Short ..	2	1	12·0	1·8	49·1	28·6	8·5	·464	·552
,, ..	2	2	13·4	1·8	45·6	30·9	8·3	·482	·614
,, ..	2	3	10·3	1·8	47·8	29·0	11·1	·680	·671
,, ..	2	4	10·9	1·9	47·2	29·4	10·6	·642	·708
Long ..	3	1	11·7	2·0	49·6	29·3	7·4	·416	·547
,, ..	3	2	12·9	1·9	48·4	28·0	8·8	·478	·575
,, ..	3	3	16·1	1·9	43·8	29·7	8·5	·540	·849
,, ..	3	4	16·8	2·0	41·2	30·7	9·3	·596	·842
Short ..	3	1	12·1	1·8	48·9	29·4	7·8	·429	·648
,, ..	3	2	12·0	2·0	47·1	29·7	9·2	·500	·606
,, ..	3	3	12·0	1·6	46·8	29·7	9·9	·587	·733
,, ..	3	4	15·2	2·1	42·2	29·0	11·5	·656	·908
Long ..	4	1	12·2	1·6	45·9	33·0	7·3	·385	·564
,, ..	4	2	13·0	1·7	45·0	30·6	9·7	·511	·675
,, ..	4	3	11·3	1·6	47·3	30·8	9·0	·603	·586
,, ..	4	4	11·3	1·6	47·2	30·9	9·0	·580	·520
Short ..	4	1	10·2	1·8	47·0	32·0	9·0	·520	·582
,, ..	4	2	12·5	1·7	45·5	31·1	9·2	·530	·619
,, ..	4	3	9·9	1·9	46·3	31·6	10·3	·680	·485
,, ..	4	4	10·6	1·8	45·6	31·8	10·2	·693	·537

APPENDIX—continued.

ANALYSIS OF INDIVIDUAL GRASS SAMPLES—*continued.*

1. PARA GRASS—*continued.*

(*b*) *Mid-wet Series.*

Stage of Growth.	Paddock No.	Division No.	Analysis of Water-free Material.						
			Crude Protein.	Crude Fat.	N-free Extract.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.
Long ..	1	1	14·7	1·8	40·5	32·8	10·2	·432	·498
,, ..	1	2	15·0	1·6	44·5	28·9	10·0	·513	·569
,, ..	1	3	16·4	1·7	42·7	29·5	9·7	·399	·593
,, ..	1	4	15·5	1·5	46·7	29·5	6·8	·351	·545
Short ..	1	1	13·1	1·2	47·3	30·9	7·5	·394	·441
,, ..	1	2	14·7	1·5	45·0	30·8	8·0	·429	·531
,, ..	1	3	16·6	1·8	41·7	29·6	10·3	·487	·689
,, ..	1	4	12·5	1·6	45·7	30·3	9·9	·432	·567
Long ..	2	1	12·0	1·6	46·7	29·9	9·8	·576	·570
,, ..	2	2	16·7	1·5	43·9	30·2	7·7	·478	·696
,, ..	2	3	13·3	1·7	45·7	29·4	9·9	·691	·600
,, ..	2	4	17·3	1·5	42·5	28·5	10·2	·565	·703
Short ..	2	1	11·9	1·9	46·7	31·1	8·4	·461	·452
,, ..	2	2	13·9	1·6	44·5	31·0	9·0	·431	·607
,, ..	2	3	13·0	1·9	46·3	29·7	9·1	·572	·469
,, ..	2	4	14·4	1·8	43·8	30·1	9·8	·466	·591
Long ..	3	1	15·0	1·9	47·3	28·3	7·4	·471	·459
,, ..	3	2	16·0	1·9	46·0	28·2	7·9	·473	·587
,, ..	3	3	17·6	1·6	42·7	28·8	9·3	·506	·691
,, ..	3	4	16·6	1·6	42·8	29·7	9·3	·480	·637
Short ..	3	1	15·2	1·6	45·2	28·7	9·3	·474	·617
,, ..	3	2	13·3	1·4	46·3	29·6	9·4	·485	·624
,, ..	3	3	15·3	1·6	43·3	29·9	9·9	·561	·760
,, ..	3	4	17·5	2·0	44·0	26·8	9·7	·506	·680
Long ..	4	1	12·3	1·6	46·7	32·1	7·3	·368	·498
,, ..	4	2	12·3	1·5	48·1	30·4	7·7	·422	·438
,, ..	4	3	14·1	1·6	46·3	30·1	7·9	·429	·407
,, ..	4	4	12·6	1·6	47·2	31·5	7·1	·441	·458
Short ..	4	1	13·5	1·8	45·7	30·8	8·2	·403	·473
,, ..	4	2	10·0	1·5	49·2	31·4	7·9	·480	·393
,, ..	4	3	10·9	1·5	46·7	32·3	8·6	·531	·543
,, ..	4	4	10·9	1·6	48·3	31·7	7·5	·482	·436

APPENDIX—continued.

ANALYSIS OF INDIVIDUAL GRASS SAMPLES—*continued.*

1. PARA GRASS—*continued.*

(*c*) *Late-wet Series.**

Stage of Growth.	Paddock No.	Division No.	Analysis of Water-free Material.†				Dry Material Per Cent. of Green Weight.
			Crude Protein.	Crude Ash.	CaO.	P_2O_5.	
Long	1	1	14·4	8·8	·638	·568	23·4
,, ...	1	2	15·1	9·7	·619	·555	23·1
,, ...	1	3	13·9	9·3	·666	·548	23·1
,, ...	1	4	14·3	8·8	·528	·530	24·0
Short	1	1	13·9	10·2	·649	·593	22·2
,, ...	1	2	18·6	11·8	1·020	·773	20·0
,, ...	1	3	14·9	9·9	·694	·617	21·7
,, ...	1	4	14·9	9·4	·413	·513	22·2
Long	2	1	17·3	10·2	·706	·632	21·3
,, ...	2	2	15·8	8·3	·628	·584	22·0
,, ...	2	3	17·4	10·3	·803	·747	20·6
,, ...	2	4	19·6	11·6	·687	·823	16·2
Short	2	1	17·9	11·1	·705	·745	16·9
,, ...	2	2	14·6	9·1	·562	·672	17·1
,, ...	2	3	17·3	11·5	·750	·688	18·8
,, ...	2	4	17·9	12·3	·710	·695	20·8
Long	3	1	14·4	9·2	·604	·466	23·3
,, ...	3	2	15·3	9·3	·486	·570	24·5
,, ...	3	3	14·8	9·7	·568	·738	22·8
,, ...	3	4	14·4	9·8	·618	·600	20·1
Short	3	1	14·4	9·9	·613	·652	23·0
,, ...	3	2	15·1	9·6	·497	·517	22·0
,, ...	3	3	15·5	10·6	·664	·855	20·6
,, ...	3	4	15·5	11·4	·715	·698	22·4

* No samples were obtained from Paddock 4.

† Crude fat, N-free extract and crude fibre were not determined in this series of samples.

APPENDIX—continued.

ANALYSIS OF INDIVIDUAL GRASS SAMPLES—*continued.*

1. Para Grass—*continued.*

(d) Mid-dry Series.

Stage of Growth.	Paddock No.	Division No.	Analysis of Water-free Material.*				Dry Material Per Cent. of Green Weight.
			Crude Protein.	Crude Ash.	CaO.	P_2O_5.	
Long	1	1	11·2	11·8	1·334	·422	26·8
,, ...	1	2	9·9	14·1	1·048	·539	25·2
,, ...	1	3	..	No sample procured			
,, ...	1	4	10·6	14·4	·978	·512	28·1
Short	1	1	12·0	10·4	·895	·576	20·5
,, ...	1	2	12·5	11·5	·992	·486	22·4
,, ...	1	3	13·1	12·1	1·020	·533	22·0
,, ...	1	4	11·6	13·1	·822	·584	24·3
Long	2	1	11·2	12·4	1·238	·455	26·6
,, ...	2	2	11·5	14·1	1·290	·536	24·4
,, ...	2	3	10·8	15·2	1·265	·536	31·9
,, ...	2	4	15·1	13·1	1·226	·584	28·3
Short	2	1	11·4	12·8	1·040	·467	24·6
,, ...	2	2	11·3	12·6	1·136	·388	23·5
,, ...	2	3	11·7	11·8	1·190	·644	23·2
,, ...	2	4	14·1	15·0	1·035	·519	20·8
Long	3	1	..	No sample procured			
,, ...	3	2					
,, ...	3	3	11·6	15·2	1·460	·707	31·5
,, ...	3	4	11·7	14·8	1·390	·488	26·9
Short	3	1	12·7	11·7	·790	·505	23·8
,, ...	3	2	11·7	11·6	1·070	·640	24·9
,, ...	3	3	11·7	14·4	1·276	·660	24·8
,, ...	3	4	12·5	13·9	1·140	·597	23·9
Long	4	1	..	No sample procured			
,, ...	4	2	10·4	12·9	1·349	·470	33·6
,, ...	4	3	9·9	14·0	1·154	·529	30·4
,, ...	4	4	11·3	18·8	1·488	·538	27·5
Short	4	1	13·4	13·7	1·072	·635	21·7
,, ...	4	2	10·6	11·7	1·130	·541	24·5
,, ...	4	3	11·0	12·0	1·178	·591	24·1
,, ...	4	4	11·5	14·9	·960	·630	24·3

* Crude fat, N-free extract and crude fibre were not determined in this series of samples.

APPENDIX—continued.

ANALYSIS OF INDIVIDUAL GRASS SAMPLES—*continued.*

2. MOLASSES GRASS.

Stage of Growth.	Paddock No.	Analysis of Water-free Material.*							Dry Material Per Cent. of Green Weight.
		Crude Protein.	Crude Fat.	N-free Extract.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.	
					(*a*) *Pre-wet Series.*				
Long ..	1	9·0	2·5	49·7	30·9	7·9	·426	·560	Not determined
Short ..	1	9·0	2·3	48·8	32·1	7·8	·407	·570	
Long ..	2	9·2	2·2	48·9	32·3	7·4	·423	·597	
Short ..	2	8·5	2·6	47·8	33·2	7·9	·376	·556	
Long ..	3	10·1	2·1	49·5	29·4	8·9	·343	·517	
Short ..	3	8·4	1·8	50·8	30·8	8·2	·315	·599	
Long ..	4	10·1	2·1	48·5	29·3	10·0	·404	·562	
Short ..	4	8·7	1·8	49·7	30·4	9·4	·342	·556	
					(*b*) *Mid-wet Series.*				
Long ..	1	10·1	1·9	46·6	32·8	8·6	·410	·536	Not determined
Short ..	1	8·7	1·6	49·3	33·1	7·3	·410	·475	
Long ..	2	8·9	1·6	48·6	34·1	6·8	·404	·440	
Short ..	2	9·4	1·7	49·9	32·1	6·9	·402	·435	
Long ..	3	9·8	1·3	45·4	35·1	8·4	·403	·884	
Short ..	3	12·7	1·4	46·5	31·7	7·7	·383	·940	
Long ..	4	9·9	1·5	49·5	32·6	6·5	·393	·597	
Short ..	4	8·6	1·6	52·5	31·0	6·3	·417	·582	
					(*c*) *Late-wet Series.*				
Long ..	1	13·2	..	..	..	6·2	·501	·574	27·3
Short ..	1	12·5	..	..	..	7·3	·513	·585	25·8
Long ..	2	13·2	..	..	..	7·9	·407	·518	24·0
Short ..	2	14·9	..	..	..	8·1	·425	·785	20·8
Long ..	3	12·6	..	..	..	7·7	·424	·640	28·0
Short ..	3	12·4	..	..	..	7·3	·378	·856	25·0
Long ..	4	No sample procured							
Short ..	4	No sample procured							

* Crude fat, N-free extract and crude fibre were not determined for the late-wet and mid-dry series of samples.

APPENDIX—continued.

ANALYSIS OF INDIVIDUAL GRASS SAMPLES—*continued.*

2. MOLASSES GRASS—*continued.*

Stage of Growth.	Paddock No.	Analysis of Water-free Material.							Dry Material Per Cent. of Green Weight.
		Crude Protein.	Crude Fat.	N-free Extract.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.	
				(*d*) *Mid-dry Series.*					
Long ..	1	9·0	..	..	..	10·1	·472	·421	32·6
Short ..	1	10·3	..	..	..	9·5	·492	·405	30·7
Long ..	2	10·1	..	..	..	7·3	·432	·509	32·0
Short ..	2	10·5	..	..	..	8·1	·425	·500	27·0
Long ..	3	10·2	..	..	..	8·1	·370	·656	29·4
Short ..	3	12·0	..	..	..	7·3	·408	·768	26·5
Long ..	4	No sample procured							
Short ..	4	9·8	..	..	..	8·4	·446	·658	33·3

3. GUINEA GRASS.

Stage of Growth.	Paddock No.	Analysis of Water-free Material.*							Dry Material Per Cent. of Green Weight.
		Crude Protein.	Crude Fat.	N-free Extract.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.	
				(*a*) *Pre-wet Series.*					
Long ..	1	8·5	1·4	46·7	32·0	11·4	·533	·429	Not determined
Short ..	1	11·6	1·6	43·2	34·1	9·5	·609	·425	
Long ..	2	8·4	1·0	45·7	36·4	8·5	·413	·470	
Short ..	2	7·9	1·0	46·9	35·3	8·9	·537	·452	
				(*b*) *Mid-wet Series.*					
Long ..	1	13·6	1·4	41·9	34·0	9·1	·574	·407	Not determined
Short ..	1	13·0	1·2	41·7	34·3	9·8	·624	·467	
Long ..	2	9·4	1·7	43·7	35·9	9·3	·576	·366	
Short ..	2	8·5	1·4	46·4	36·3	7·4	·544	·342	
				(*c*) *Late-wet Series.*					
Long ..	1	11·9	..	..	..	11·2	1·000	·374	32·0
Short ..	1	13·0	..	..	..	9·6	·714	·462	28·0
Long ..	2	16·2	..	..	..	12·2	·725	·602	27·8
Short ..	2	15·9	..	..	..	10·9	·662	·644	25·0
				(*d*) *Mid-dry Series.*					
Long ..	1	6·8	..	..	..	15·6	1·695	·276	35·1
Short ..	1	12·0	..	..	..	10·3	1·012	·543	26·2
Long ..	2	10·1	..	..	..	12·3	·884	·488	32·2
Short ..	2	10·6	..	..	..	11·8	·905	·508	26·1

* Crude fat, N-free extract and crude fibre were not determined for the late-wet and mid-dry series of samples.

APPENDIX—continued.

ANALYSIS OF INDIVIDUAL GRASS SAMPLES—*continued.*

4. Sour Grass.

Stage of Growth.	Paddock No.	Analysis of Water-free Material.*							Dry Material Per Cent. of Green Weight.
		Crude Protein.	Crude Fat.	N-free Extract.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.	
				(*a*) *Pre-wet Series.*					
Long ..	3	8·4	0·6	46·9	34·9	9·2	·411	·469	Not
Short ..	3	8·7	0·8	46·6	34·4	9·5	·363	·478	deter-mined
				(*b*) *Mid-wet Series.*					
Long ..	3	12·5	1·7	45·7	31·1	9·0	·440	·606	Not
Short ..	3	13·0	1·5	45·6	29·0	10·9	·449	·527	deter-mined
				(*c*) *Late-wet Series.*					
Long ..	3	11·3	..	..	..	11·1	·536	·585	22·2
Short ..	3	11·1	..	..	..	12·1	·554	·566	23·2
				(*d*) *Mid-dry Series.*					
Long ..	3	No sample procured							
Short ..	3	8·8	..	..	..	13·7	·804	·427	23·7

* Crude fat, N-free extract and crude fibre were not determined for the late-wet and mid-dry series of samples.

5. Russell River Grass.

Stage of Growth.	Paddock No.	Analysis of Water-free Material.*							Dry Material Per Cent. of Green Weight.
		Crude Protein.	Crude Fat.	N-free Extract.	Crude Fibre.	Crude Ash.	CaO.	P_2O_5.	
				(*a*) *Pre-wet Series.*					
Long ..	1	7·9	1·4	45·5	36·1	9·1	·474	·341	Not
Short ..	1	7·6	1·1	45·1	37·9	8·3	·378	·334	deter-mined
				(*b*) *Mid-wet Series.*					
Long ..	1	11·5	1·6	46·4	33·1	7·4	·387	·425	Not
Short ..	1	13·4	2·0	46·4	29·5	8·7	·436	·449	deter-mined
				(*c*) *Late-wet Series.*					
Long ..	1	11·4	..	..	..	9·1	·392	·410	26·5
Short ..	1	12·5	..	..	..	10·7	·360	·460	24·8
				(*d*) *Mid-dry Series.*					
Long ..	1	7·6	..	..	..	11·8	·665	·239	26·9
Short ..	1	11·7	..	..	..	10·8	·635	·310	25·0

* Crude fat, N-free extract and crude fibre were not determined for the late-wet and mid-dry series of samples.

AN INVESTIGATION OF THE RAT PEST PROBLEM IN QUEENSLAND CANEFIELDS: 1. ECONOMIC ASPECTS.

By W. A. McDOUGALL, M.Sc., Entomologist, Bureau of Sugar Experiment Stations.

SUMMARY.

1. *The fragmentary published records of rat damage to sugar cane in Queensland prior to* 1935 *are reviewed and evidence of rat damage collected since that year is presented. Appreciable rat attacks are shown to occur only periodically and usually sporadically.*

2. *An account is given of the form of rat damage to cane, and it is shown that the damage often is of the nature of a nuisance, in that there is interference with harvesting and with general farm routine.*

3. *The various factors contributing to economic loss are discussed. It is concluded that usually not more than one unit of C.C.S. (sugar content) is lost in cane harvested from fields subjected to heavy and continued attack, and that actual cane tonnage losses are seldom high. The imposition of penalty harvesting rates often converts the nuisance factor into an economic loss to the farmer.*

INTRODUCTION.

Rats and other rodents have been reported from many parts of the world as field pests in agricultural, pastoral, and allied industries. Much has been written on this subject but the control of field rats is still far from satisfactory.

So far as the rat pests of sugar cane in Queensland are concerned few records of a detailed nature were published prior to 1935; this does not mean that these pests were absent, nor that they were neglected entirely, although it is perhaps a reflection of the status of rats as pests prior to that date. From such earlier references as are available it would seem (as has been the case during the past ten years) that appreciable rat attacks on cane crops occurred only periodically and usually sporadically. Earlier published references to the problem are rather fragmentary, since observers were usually associated with sugar mills or with organizations that did not normally publish the results of their efforts, which in any case were seldom continuous and were mostly concerned with the experiences of the moment and not with the provision of data for the guidance of future investigators. These almost purely topical references should therefore be viewed in perspective and should not be accepted without due

reservations; such as are here referred to have been cited in the text and have not been included in the formal list of references.

In the second volume of *The Australian Sugar Journal* (1910, p. 269) mention is made of the varieties of rats found attacking sugar cane, and later in the same year (*ibid*, p. 367) the depredations of the pests were discussed by the Johnstone River Canegrowers' Association; and subsequently (*ibid*, p. 429) various rat poisons and methods of baiting were recommended by Mr. C. E. Jodrell, a prominent cane grower. In the issue for July, 1911 (p. 225), it was recorded that rats descended upon the Lower Burdekin district in thousands, while they were reported to be numerous at Gordonvale in 1915 (*Aust. Sugar J.*, 1916, p. 737).

In 1920 the Bureau of Sugar Experiment Stations initiated a system of district inspections by a very small staff of travelling officers, non-technical reports of the inspections being published in *The Queensland Agricultural Journal* and *The Australian Sugar Journal* from 1920 till 1932, when this system was discontinued. From a study of such reports it is apparent that in 1922 rat damage in North Queensland was much more severe than usual, especially in the Mulgrave and Herbert River areas. The next two years evidently witnessed a decline, but in 1925 damage was again reported as being severe in the far northern cane districts. Considerable damage was reported at Tully and in the late-harvested cane at Ingham, in 1927, but otherwise only light infestations were reported from northern, central, and southern cane districts during the period 1926-28. No specific mention is made of the incidence of the pests over the years 1929-33, but in the June, 1932, issue of *The Queensland Agricultural Journal* (p. 299) Kerr summarized the then existing knowledge of rat control in canefields and referred to poisoning campaigns then being carried out by North Queensland Cane Pests Boards.

The year 1934 saw the commencement of a distinctly new phase in the investigation and treatment of the rat problem in Queensland canefields. Kerr (1934), referring to the state of the crop in the more northern areas, stated:— "A large percentage of the crop was damaged by rats, grubs, and borers"; while Bell (1934) recorded that "damage to cane on account of the attack by rats has been considerably greater than in previous years and in the aggregate has been greater than that caused by any other pest." Gard (1935), in a summary of the rat problem in the Macknade Mill area (Herbert River) for the years 1930-34, indicated that rats were prevalent there during 1932, 1933, and 1934.

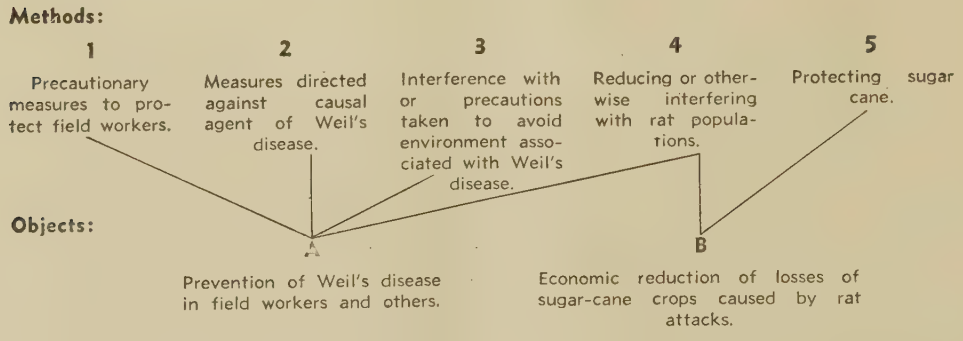
At this time, also, the importance of the rat control problem was increased by an outbreak of Weil's disease in the Herbert River district. Morrissey (1934) has recorded that in October, 1933, there appeared the first reported series of cases of a disease which was later diagnosed as Weil's disease. Laboratory and epidemiological investigations by Cotter and Sawers (1934) demonstrated the relationship between the causal agent (*Leptospira icterohaemorrhagiae* Inado and Ido) of this disease and rats in canefields, and particularly noted the

incidence among cane cutters and also among cane growers whose exposure approximated that of cane cutters. Thereafter, the prevention of Weil's disease became part of the rat control problem of certain North Queensland sugar-cane districts and one immediate result was the institution by State Health and Medical Services (Cilento, 1936) of a comparatively large-scale anti-rat campaign in the Herbert River district; this campaign was continued for two years.

In the past rats in canefields have been considered of minor importance, except in certain exceptional years which, in most instances and in all districts, have been well spaced. Interest in these pests has been sustained, in the face of declining crop losses, mainly as a result of the association of field rats with the transmission of Weil's disease.

In 1935 the author was assigned to special rat investigations, the undertaking of this work being preceded by a period of special study of rodent zoology at Sydney University. Progress reports of certain phases of this investigation have been published from time to time (McDougall, 1935-40), while Bell (1935-40) has given summarized accounts of the yearly depredations of the pest and of investigational work carried out by the Division under his control. Reports on the medical aspects of the problem and the concomitant industrial repercussions have been made by Cotter (1935), Cilento (1936), and Sawers (1938). Extensive topical references may be found in various sugar journals, while certain aspects have been debated annually by conferences of Cane Pests Boards functioning under the provisions of "*The Sugar Experiment Stations Acts,* 1900 *to* 1941."

The scope of investigations carried out in Queensland during the past ten years may be represented schematically as under:—


Methods:
1
Precautionary measures to protect field workers.
2
Measures directed against causal agent of Weil's disease.
3
Interference with or precautions taken to avoid environment associated with Weil's disease.
4
Reducing or otherwise interfering with rat populations.
5
Protecting sugar cane.
Objects:
A
B
Prevention of Weil's disease in field workers and others.
Economic reduction of losses of sugar-cane crops caused by rat attacks.

According to Cilento (1939):

"... the rat menace and the leptospirosis problem are associated with particular localities, and sometimes with very restricted areas. Leptospirosis, in fact, is a focal disease.

"Cases of leptospirosis have occurred in several instances in the same groups and on the same farms in successive years. They have several times occurred significantly when lowlying ground is being cut, and have usually, but not always, been accompanied by a fairly heavy rat infestation."

It would seem, therefore, that a superimposed but restricted environment has broadened the rat problem in only a few localities. The investigation undertaken by the author has been concerned primarily with object "B" above. Studies such as those on rat populations and their behaviour in the field have also a medical interest. Nevertheless, in this series, only deductions directly and strictly concerned with the geographically wider agricultural aspect have been considered.

The Form of Rat Damage to Sugar Cane.

Rats damage sugar cane primarily by gnawing the stalks at night. As a rule the rind of any one internode is broken in one distinct place only (Plate 1), and such damage is here termed a rat bite; *i.e.*, the recording of three "bites" on a stalk means that three internodes have been damaged by rats. Actually,

Plate 1.
STALKS OF THE VARIETY BADILA DAMAGED BY RATS.

any particular bite may be the result of more than one rat, feeding for two or three nights, or it might have provided a single rat with but a part of its nightly intake. Field cage experiments have shown repeatedly that a large bite may be the work of one small rat over two or three nights or that of several young rats during a single night. Also, a large rat may start a number of bites during the first night and these may be enlarged by it, or by others, during that or succeeding nights.

Rats are wasteful feeders and associated with their bites there is usually some finely chewed cane tissue or frass, either scattered or in loose piles. Under certain conditions in Queensland several other indigenes—such as opossums (*Trichosurus* spp.), rat-kangaroos (*Potorinae*), wallabies (*Macropus* spp.), the eastern swamp hen or red-billed coot (*Porphyrio melanotus* Temminch), and the brush or scrub turkey (*Alectura lathami* Gray)—attack cane stalks in a somewhat similar manner. However, the form of damage is usually distinctive. For example, in the case of the turkey the scored cane tissue shows distinct beak marks; many of the marsupials damage the growing parts of stalks also, and they often leave some of the discarded but chewed stalk tissue in loosely cohesive lumps.

The number of bites on any stalk may be as many as the number of uncovered internodes; the attack may be near ground level and/or higher up the stalk. Sometimes only a few stalks, in stools scattered here and there throughout the field, may be attacked; on other occasions fields of pure stands of any variety may receive the attentions of the pests either throughout the fields or in irregular patches. Often it is lodged cane which is chiefly damaged, but it may be cane growing in those parts of the fields near creeks or other watercourses, around seepages or swamps, or close to ground cover (shrubs, weeds, and grasses) or "scrub" (rain forest); occasionally cane near buildings is selectively damaged by rats. However, it does not follow that all cane in these situations will be attacked by rats: this is far from fact even in years of large and widespread rat populations. When "supplies"* of a soft variety like H.Q.426 or H.Q.285 are planted in a field of a harder variety such as P.O.J.2714 or P.O.J.2878, the stools of the supplies are sometimes completely eaten out, while little or no damage is inflicted on the harder cane. Similarly, rows of softer varieties planted near or amongst harder canes, or only fields of more susceptible canes, may be selected for attack.

In the northern and central areas, the cane is planted from autumn to late spring, the resultant crops being harvested during the latter half of the succeeding year; it is only in exceptional circumstances that two-year crops are grown in these areas. Rat attack normally commences during the colder weather† in June and July, and continues until November at the latest. Occasionally damage is observed as early as May, some species of rats having a

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* *I.e.*, replants of cuttings which have failed to germinate.

† It is of interest to note that, in a personal communication dated 20th November, 1936, received from D. H. Doggrell, a State forestry officer stationed at Imbil, South Queensland, it is stated that rat damage in reforestation areas is confined to the winter months.

tendency to attack cane earlier than others. Occasionally, also, there occurs "out-of-season" damage; as, for example, when small patches of cane are surrounded by water for some time during the rainy season and then temporarily harbour concentrated rat populations quite abnormal for that time of the year; or again when small isolated blocks of cane are left standing late in the harvesting season on rat-infested farms. Within the normal period of rat attack there may be considerable variation in time of infestation in different years. Depending upon current conditions, attack may commence at any time during this period, perhaps early August or even October, and either continue unabated till the end of harvesting or gradually decline.

Cultivated young cane is seldom attacked by rats, and it is often stated that crops are attacked only when and because the sugar content begins to rise. This idea has doubtless developed because it so happens that early-maturing canes such as H.Q.426 and H.Q.285 are soft canes and therefore "rat susceptible"; this applies also to N.G.15 (Badila) and S.J.2, both canes of high sugar content. On the other hand the less widely grown P.O.J.2725, 7R.428 (Pompey) and Co.290, if grown in suitable localities, are attacked by rats early in the winter, and early maturity and high sugar content are not characteristics of these varieties. No characteristic of the cane itself (*e.g.*, sugar content or maturity) has as yet been correlated with the time of occurrence of a mid- or late- season rat attack.

The visible effects of rat attack on sugar cane are usually very obvious (see Plates 2, 3, 4 and 5). So far as is known rat attack on sugar cane in the field does not influence the quality of sugar eventually manufactured. With some slight adjustment, depending on harvesting methods, cane payments to the farmer are made on the basis of cane weight and sugar content and for the purposes of assessing magnitude of economic losses usually these factors only are taken into account.

The Assessment of Economic Losses Caused by Rats.

Pemberton (1925) reported the losses due to rat damage in Hawaiian canefields. These careful estimates were based on comparative analyses and weighings of rat-damaged and non-rat-damaged cane stalks, together with an allowance for dead cane left in the field after harvesting. The estimated loss of 19·17 per cent. (in tons of sugar) of the potential crop on two plantations in 1922 was considered by Pemberton to be vastly more than would have been estimated in the absence of such analyses. It is reported from the same source that further studies, conducted on similar lines, amply confirmed these earlier results. In another series of analyses comparatively slightly damaged cane—only one to three bites per stick—was sampled, and even here crop loss (weight × sugar content) was found to be 14·9 per cent.

Gard (1935), using methods somewhat similar to those reported by Pemberton in Hawaii, estimated losses due to rat damage in the Macknade Mill

Plate 2.
THE VARIETY BADILA AFTER RAT ATTACK AND PRE-HARVEST BURN.

Plate 3.
ANOTHER FIELD OF THE VARIETY BADILA, GROWN ON STONY GROUND IN THE FARLEIGH MILL AREA (MACKAY), AFTER RAT ATTACK.—This field was not harvested in a year of excess production.

Plate 4.

A Field of the Variety P.O.J.213, in which 98.5 per cent. of Stalks were Damaged by Rats.—Photographed after burning of field.

Plate 5.

A Rat-damaged Field of the Variety P.O.J.213 after Pre-harvest Burning.

area to be 8 per cent. on the 200,732 tons of cane crushed during 1933, a season of heavy rat damage. This loss was made up as follows:—

	Per cent.
Loss in weight of harvested cane due to rat damage	5.5
Loss due to deterioration in damaged cane (*i.e.*, loss in sugar content)	1.5
Loss due to damaged cane being discarded in the field ..	1.0
Total	8.0

Comparing the magnitude of this damage with the higher figures reported by Pemberton, Gard points out that the greater age of the cane at harvesting in Hawaii must be taken into account. In this connexion Barnum (1930) states that investigations at one Hawaiian sugar plantation indicated that both rat and borer damage increased rapidly after the canes were 16 months old.

The yearly fluctuations in percentage of stalks damaged by rats and in percentage loss in weight of cane delivered to the Macknade Mill over a number of years are set out [1] as under:—

Year.	Percentage of rat-damaged stalks.	Percentage loss in weight.
1930	13.0	Not determined
1931	18.7	3.0
1932	23.8	4.2
1933	33.3	5.4
1934	32.8	5.3
1935	19.2	4.9
1936	5.3	1.1
1937	10.9	2.6
1938	10.7	2.4
1939	10.1	2.2
1940	5.6	1.3
1941	5.4	1.2
1942	20 (approx.)	4 (approx.)

In the adjoining Victoria Mill area losses in weight only have been reported [2] for four-year periods as follows:—

1928-1931	14,000 tons of cane,	or 1.6 per cent.
1932-1935	32,500 „ „ „	3.4 „ „
1936-1939	4,000 „ „ „	0.4 „ „

[1] Gard (1935 and 1938-1942).

[2] Aust. Sugar J., Jan., 1940, p. 563.

The percentage of rat-eaten stalks for this area during the period 1934-1938 and for 1940 are given [1] as under:—

1934	14.7
1935	11.7
1936	3.9
1937	3.4
1938	3.2
1940	3.7

In making the above computations the mill area was used as a unit, and samples were taken periodically from the cane delivered to the mill for crushing. The figures include no allowance for damaged cane left in the field.

Owing to the quantitative and qualitative variation of both rat damage and sugar cane from locality to locality, from farm to farm, and from field to field, it is considered that the assessing of losses under Queensland conditions should be made, where possible, with the farm as a unit. This subdivision would permit the readier detection of anomalies as well as indicating the distribution of damage—a point of very considerable economic importance.

Economic losses resulting from rat attack on sugar cane may be considered under the following headings:—

1. Loss in weight of harvested cane;
2. Loss in sugar content of harvested cane;
3. Loss due to interference with harvesting;
4. Loss in field yields as expressed by reduction of cane tonnages;
5. Loss due to interference with general farm routine;
6. Rat control costs.

These are discussed in turn hereunder:—

1. The following are submitted as instances of what may be obtained when attempts are made to calculate loss in weight of harvested cane by comparing the weights of rat-eaten and non-rat-eaten stalks.

(*a*) Two acres of Badila ratoons were harvested early in the season to avoid further rat damage. Counting and weighing of stalks were carried out after the cane had been cut and was lying in bundles in the field. It was found that 55·7 per cent. of the stalks had been attacked by rats, with an average of four bites per stalk; damaged cane had been further attacked by the weevil borer *Rhabdocnemis obscura* Boisd. The total yield of harvestable cane obtained from this field was 35 tons 7 cwt.; equal numbers of damaged and undamaged stalks aggregating 17 tons 5 cwt. were weighed, and it was found that a difference in weight of 1 ton 3 cwt. existed in favour of the undamaged stalks in this large sample. All rat bites were carefully examined and compared with similar bites inflicted under controlled conditions on the same variety, and the actual loss in weight of cane (due allowance being made for drying out)

[1] Aust. Sugar J., Jan., 1939, p. 596, and Jan., 1941, p. 509.

was calculated. It was found that in this sample of 17 tons 5 cwt. the actual loss in weight due to rat bites was of the order of 400 lb. It follows, therefore, that the rat attack was selective, lighter stalks receiving preference.

(*b*) The harvestable cane in a 3¼-acre field of P.O.J.2878 contained 37·2 per cent. of rat-eaten stalks; 95·7 per cent. of such stalks were found to be the smaller-barrelled, lighter type of stalk often encountered in this variety. The undamaged stalks were significantly heavier than the damaged stalks, the ratio of weights being 5·3 : 3.

(*c*) In a 12-acre block of Badila, one acre, in a damp situation adjoining a creek and rain forest, was infested with rats. Within this acre all harvestable stalks (estimated weight 20 tons) were inspected and counted; 53 per cent. were found to be damaged, with an average of 2-3 bites per stalk. Weighing of equal numbers of damaged and normal stalks showed no significant difference in aggregate weights, while the actual loss due to rat bites was of the order of 150 lb.

(*d*) In a field similar to that of (*c*), weights of samples of equal numbers of stalks were recorded as follows:—

Rat-damaged: 235, 135, 140, 157, and 157 lb.
Mean 165 ± 18 lb.
Non-rat-damaged: 167, 107, 127, 177, and 80 lb.
Mean 132 ± 18 lb.

The standard error of the difference between means, viz., 25·6, is not significant at the 5 per cent. level.

Neither rat stalk selection nor losses in weight due to rat attack can be traced statistically by weighings in cane of the type encountered here and in (*c*).

The investigations indicate that it is impracticable to calculate loss in weight of harvestable cane (*i.e.*, cane delivered to the mill) by comparing the weights of rat-eaten stalks and non-rat-eaten stalks. Probably the most obviously incorrect results are obtained when using this method in fields with a very high proportion of damaged stalks. The use of this method assumes that rats attack stalks at random. This has been found to be far from correct (see (*a*) and (*b*) above). In fields where varieties and environment vary stalk selection is obvious; *e.g.*, stools of softer "supplies" or patches of lodged cane may contain the only rat damage in that field. Sometimes a careful inspection of stalks within a typical rat environment may result in the finding of teeth marks on many undamaged stalks. It has been observed that stalk selection by rats is involved, and dependent not only on cane varieties and type of crop and growth but also on the species of rats and the make-up of their populations, on seasonal conditions, and on time of infestation. Furthermore, it seems that, as used, the comparison of weights of rat-eaten and undamaged stalks, as indicative of loss in weight of harvested cane, also assumes that there is little variation in weight between stalks themselves within any particular field. Kerr (1932), discussing

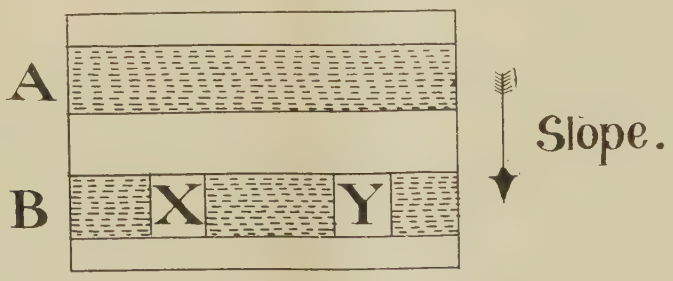
field sampling for the determination of sugar content, remarks that the range of variation of stalk weights was extremely large in fields considered by him. It is common experience that there may be a large variation in weight even between stalks of the same stool. It follows, therefore, that if rats by some possibility did select stalks absolutely at random very careful sampling methods would have to be formulated and used to obtain statistically sound results.

2. The foregoing remarks on the validity of the comparison of weights of damaged and undamaged stalks also apply in principle to comparisons of sugar content. However, there are few records of significant loss of sugar content as a result of rat depredations in Queensland canefields.

Gard (1935) has reported a loss which approximated 2½ units of C.C.S.* in samples of cane in which 50 per cent. of stalks were rat-eaten and which were taken towards the conclusion of the crushing season, *i.e.*, in circumstances where deterioration was likely to be much greater than it would have been earlier in the season.

As a result of numerous analyses conducted by the author it would appear that in Queensland there is less fundamental variation in sugar content of samples of damaged and sound cane, grown in the one environment, than there is in their respective weights. This conclusion is in general accord with the observations of Kerr (1932). Rat-eaten cane frequently exhibits comparatively low C.C.S. content, but this is often due to the environment of the damaged cane. Samples were taken from lodged cane (a frequent indication of a rat-favourable environment) in a 12-acre field of M.1900 Seedling free of rats, and some of these samples were as low at 12·3, whereas the standing cane was milled for a C.C.S. of 16·1.

During 1936 a field sloping from a hillside to a grassy creek was watched for rat damage. Early in June two small areas (X and Y) of the more rankly growing cane near the creek, where rat damage could be expected, were protected from rats in accordance with the layout figured below.



* C.C.S., or Commercial Cane Sugar, is the usual Queensland standard measure of available sugar in cane. It is derived from the empirical formula—

$$\text{C.C.S.} = \frac{3P}{2}\left(1 - \frac{5 + F}{100}\right) = \frac{B}{2}\left(1 - \frac{3 + F}{100}\right)$$

Where P = pol in first expressed juice,
B = brix in first expressed juice,
F = fibre in cane.

At the end of August, C.C.S. samples were taken from A, representing that part of the field not damaged by rats; from B (excluding X and Y), that part of the field damaged by rats (32 per cent. of damaged stalks with an average of three rat bites per stalk); and from X and Y, as examples of undamaged cane from the rat environment. Recordings were:—A 15·3 units of C.C.S., B (less X and Y) 13·3, and X and Y 13·1. When the cane from a field of this type is delivered to a mill it is probable that the farmer would consider rat attack had lowered C.C.S. by about two units in the lower portion of the field. The check plots, X and Y, demonstrate what is a fairly common occurrence: rat damage and low C.C.S. may be co-existent, but actually independent of each other.

In further experiments there were compared samples, each of 25 stalks selected at random from stools of evenly grown crops, and which had suffered similar rat damage over approximately the same time. The following are the C.C.S. results of a typical series of analyses:—

Rat-damaged samples: 11·62, 13·32, 12·87, 13·90, 14·57, and 13·20.
Mean = 13·25 ± ·41.

Sound samples: 14·31, 14·40, 13·43, 14·42, 13·43, and 14·23.
Mean = 14·04 ± ·19.

The standard error of the difference between means—viz., ±0·59—is not significant at the 5 per cent. level.

Figures of this nature are of more interest if further sampling is undertaken in the same rat-infested fields towards the end of the harvesting season, and on some occasions significant differences between sugar contents of the two classes of cane have been found. These differences depend upon the extent and degree of damage due to early attacks and whether attacks have been sustained throughout the season. It appears probable that, in most instances, not more than one unit of C.C.S. is actually lost in harvested cane from fields suffering heavy and continued attack.

3. It is generally agreed that rat attack on sugar cane creates difficulties in harvesting. Stalks, although rat-bitten, may still have normal sugar content at harvesting time and may suffer negligible loss in weight. If bitten some distance from the ground the top portion may have fallen over; if bitten near the ground the stalk may be lodged. Furthermore, stalks may break into pieces when hit at the base with the cane knife or when handled by the cutter; sometimes breaking and/or bending does not occur until the bundles are lifted for loading. Some infestations have a purely nuisance effect, which is thus exhibited at harvesting time, whilst with others economic loss is an additional factor. The relative magnitudes of and the relationship between these two factors will depend to some extent on the variety of cane, the rat species responsible for the attack, the type of attack, the conditions under which harvesting is carried out, and the quality of the crop.

In fields of the short, thick S.J.2 or Badila, or of lodged soft varieties, heavy attack by the pest means that many stalks may be broken up into short

lengths. Normally these, together with dead and dried-out stalks, are left lying in the field. On the other hand, in the field illustrated in Plate 4, although the P.O.J.213 had been heavily attacked (98·5 per cent. rat-bitten stalks), the one or two bites per stalk were near ground level, and the fallen cane could be harvested. Samples taken immediately after burning resulted in mill average C.C.S. values, and probable losses in tonnage were estimated as low. Nevertheless, due to the nuisance factor, this small field was not harvested, and a small intrinsic loss became in effect a comparatively large one. Admittedly this is an abnormal case, but it serves to illustrate the point. Actually infestations resulting in complete loss are rare and usually confined to poorly grown crops where, in all instances, the nuisance factor quickly becomes converted to a true economic loss.

In Queensland a slight increase in the cutting costs of cane attacked by rats is allowed. In recent years, and particularly in the northern areas, when extra farm labour is employed for harvesting, these increases are often the largest monetary loss to the farmer which can be debited to rat attack on cane.

4. There is often little relationship between the percentage of stalks attacked in any field and the degree of damage inflicted, as expressed by the average number of bites per stalk; many contributory factors are concerned, not the least being the thickness of the stalk and the tendency of the damaged stalk to remain upright or in one piece.

Careful observations indicate that the loss of weight in harvested cane is not necessarily the heaviest tonnage loss. The best indication of serious rat damage is usually the amount of damaged cane left in the field after harvesting. The accurate estimation of such cane is often difficult. (In the field depicted in Plate 5, for example, the badly damaged thin variety cane had dried out and some of it was partially or completely burnt during the pre-harvest burn.) In practice two methods of estimating tonnage losses may be used singly or conjointly, depending on the degree of damage. If the damage is extensive the difference between a thorough estimate of probable yield if rat attack had not occurred and weight of cane actually delivered to the mill may be taken as the tonnage loss. If damage is light the amount of cane left in the field should be determined. It has been found that these methods are reasonably reliable; they take into account fairly fully and accurately the several contributory factors concerned, check the inflated losses often calculated by other methods, and also serve to place rat damage in a better perspective. This applies particularly to conditions during normal years when appearance of the damaged cane, plus an almost purely nuisance factor, are often given an inflated economic loss value.

5. Because of rat attack a field may be harvested earlier than would normally be the case and, depending largely upon the variety, this may result in lower C.C.S. returns from that field. Such assessments should, however, be handled with care; for, when the farm is taken as the unit and due consideration is given to what would have been the normal harvesting sequence, equalizing or compensatory factors are often found to have functioned.

Early harvesting as a result of rat attack may result in poor ratoons, and this together with interference with sources of plants and damage to stand-over fields constitute the chief effects of rat attacks on crops for the succeeding year.

6. It has been stated (McDougall, 1940) in discussing the sugar-cane grub pest *Dermolepida albohirtum* Waterh. that "after all the pest is more or less the immediate concern of the individual farmer rather than that of the community as a whole." The same applies to the rat pest. However, in attempting to reduce economic losses caused by these pests it is generally accepted that for some phases of the project collective action is the more expedient, efficient, and practicable. For administrative reasons the collective unit is often a mill area and it is impossible to take the farm as a unit when cost of attempted rat control is debited as a loss due to rat attack.

Under the present communal system of pest control in Queensland cane-fields the cost of rat control does not bear heavily either on the individual farmer or on his district. In certain mill areas the cost of material alone has on occasion amounted to over £2,000 in one year, but this is a peak value, and in most instances a few hundred pounds would cover costs of material in even the worst rat years. Direct administrative costs of applying control measures are low.

Over the past seven years the author has made estimates of tonnage losses caused by rat attacks on sugar cane. In fields scattered throughout a district, losses per farm varying from less than one ton to 50 tons have been assessed, and it has been noted that a large number of infestations did not warrant much attention, so far as tonnage losses were concerned, despite fairly high counts of damaged stalks.

It may be said that, in most districts, no satisfactory statistics on true economic losses from rat damage to cane are available. The reasons for this appear to be:—

(*a*) Sporadic nature of attack;

(*b*) Variation in annual incidence, heavy damage being abnormal;

(*c*) Heavy damage, when it does occur, is seldom general but is usually confined to a comparatively small number of farms in a mill area.

Appreciable tonnage losses are not evenly distributed and have to be borne by a few, and in some districts there is a tendency to convert, by penalty harvesting costs, a nuisance factor into a monetary loss to the farmer. These facts render the problem of lessening losses caused by rat attacks on sugar cane in Queensland more difficult than would otherwise be the case.

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AN INVESTIGATION OF THE RAT PEST PROBLEM IN QUEENSLAND CANEFIELDS: 2. SPECIES AND GENERAL HABITS.

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SUMMARY.

1. *Eleven Murid species are recorded from northern and/or central Queensland canefields. Five are associated with damage to sugar cane.*

2. *Rattus conatus is the most important economic rat pest of cane, owing to its ability to sustain mass attacks. Melomys littoralis is second in importance: in some years when the greater proportion of the effect on cane is of a nuisance order only this is the species mainly responsible. The status of M. cervinipes as a pest of cane is indefinite, as its real distribution in years of heavy rat populations is not known. Rattus rattus and R. culmorum are of little direct economic importance.*

3. *The three indigenous Rattus species—R. conatus, R. culmorum and R. assimilis—are burrowing rats. R. conatus lives in damp, friable soil with a close and substantial ground cover. R. culmorum has been found in or near sugar districts only in sandy, grassy places amongst mangrove creeks and marine swamps. R. assimilis is confined to rain forest and adjacent localities. M. littoralis spends much of its time off the ground and builds nests in vegetation; it is often associated with R. conatus but is also found in "palm tree" swamps and in sparsely covered grass-shrub country. M. cervinipes has many characteristics similar to those of M. littoralis, but its native habitat is rain forest.*

INTRODUCTION.

The common collective name "rats" was used in all early references to damage by these pests in Queensland sugar-cane fields. In 1935 E. LeG. Troughton, of the Australian Museum, Sydney, tentatively identified three species, submitted by Gard as damaging cane in the Herbert River district, as *Rattus rattus* L., *Rattus culmorum* T. & D., and *Melomys littoralis* Lönn (Gard, 1935). During the succeeding four years these names were generally used in publications on various aspects, both medical and economic, of rat infestation of Queensland sugar-cane fields. During this period an ecological survey in a number of mill areas was undertaken by the Bureau of Sugar Experiment Stations, and it soon became apparent that the accepted identifications of some of the indigenous *Muridae* were not sufficiently well founded. It was observed that two species of naked- or file- tailed rats (*Melomys* spp.) damaged cane in Queensland; furthermore, a species of *Rattus* trapped in canefields in the Mackay

district in 1936 was found by Troughton (1939) to be the true *culmorum*. The species which had become so well known by that name for four years was then referred to Thomas's *conatus*.

Mr. Troughton has carried out a considerable amount of work on the nomenclature of Murid species inhabiting canefields and adjacent environments, and has identified the following which may be taken in those habitats in northern and/or central Queensland cane districts:—

Rattus rattus Linné (House rat);

Rattus conatus Thomas (Field rat or field ground rat);

Rattus culmorum Thomas and Dollman (Brown field rat or brown ground rat);

Rattus assimilis Gould (Scrub rat or scrub ground rat);

Melomys littoralis Lönnberg (Small khaki rat);

Melomys cervinipes Gould (Large khaki rat);

Hydromys chrysogaster reginae Thomas and Dollman (Water rat);

Xeromys myoides Thomas;

Uromys caudimaculatus Krefft;

Thetomys gracilicaudatus ultra Troughton;

Mus musculus Linné (House mouse).

Rattus norvegicus Erxlelen is, according to Pemberton (1925), the species most destructive to sugar cane in Hawaii. This rat is known to be present in some cities and towns in Queensland sugar-cane districts but it has never been trapped or recorded from canefields.

Common names from different sources have been included in the above list for those species of most concern in the rat problem in Queensland canefields. The names given for the two introduced species, *R. rattus* and *M. musculus*, are well known in this country, and are more suitable for use in cane districts than are the alternatives, black rat or ship's rat, and European mouse. Gard (1935) used "field rat" for the species then known as *R. culmorum* and since identified as *R. conatus;* this name is an apt one for sugar-cane areas, and an added colour designation is sufficient to separate the true *culmorum* from *conatus*. *R. assimilis* is the indigenous *Rattus* species found in rain forest ("scrub") and sometimes also in cane adjacent to it; hence the suggested name "scrub rat" for this species. The secondary name "ground rats" for the three burrowing *Rattus* species (*conatus, culmorum*, and *assimilis*) is sometimes useful. *Melomys littoralis* is known as "tree rat," "banana rat," "khaki rat," or "Melomys" in the Herbert River district; but following the more extensive trapping in other districts in recent years it is also necessary to consider *M. cervinipes* as a cane pest. The chief difference in appearance between these two *Melomys* species is size; their colour is distinctive, so the common names "small khaki rat" and "large khaki rat" should serve to identify them. The common water rat found throughout coastal Queensland is *H. c. reginae*.

Figure 1.
OUTLINE MAP SHOWING THE LOCALITIES REFERRED TO IN THE TEXT.

Troughton (1941), in discussing *R. conatus,* remarks that "it is desirable to retain the specific distinction of the cane-fields *conatus* to simplify field investigations and the tabulation of research." Unfortunately for field workers, appreciations of this nature are only recent and in the past authors through force of circumstances have apparently concentrated on the detection of slight morphological differences, without due regard to the possible variation within a species. There is a voluminous descriptive literature on Australian *Muridae,* based chiefly on morphology, but with many species the specific differences and relationships are not clear or well established. Under such circumstances it is considered undesirable, at this juncture, to re-describe in detail (at a field station) any species associated with the rat pest problem of sugar cane; the checking with existing descriptions and the addition of further data should prove more useful. The listing of subspecies, as follows on subsequent pages, should be taken as merely formal. Outside the northern and central sugar areas, which extend from Mossman to Carmila (see Figure 1), only meagre information on the ecology and habits of the indigenous Murid species—with the exception of *R. assimilis*—is available. Without such data it would be unwise to accept completely records of distribution based on nomenclature derived from morphology alone.

It has been found that, to be of material use, field observations on rats should have continuity and should cover a wide geographic range under different seasonal conditions. Authentic enlargement of the knowledge of distribution of canefield species would serve a useful purpose. Although the northern and central sugar-cane districts cover a large area, the climatic environment is substantially uniform throughout; observations on the same species elsewhere would serve both as a check on canefield rat work and as a help in improving the interpretation of data collected in these areas.

Animals other than rats and mice occasionally fill rat traps set in canefields and adjacent places; these include the brush or scrub turkey (*Alectura lathami* Gray), the Pheasant Coucal (*Centropus phasianinus* Latham), rails (*Rallidae*), the stone curlew (*Burhinus magnirostris* Latham), quails (*Turnicidae*), bandicoots (*Isoodon torosus* Ramsay and *Perameles nasuta* Geoffrey), several species of snakes (*Ophidia*), the blue tongue lizard (*Tiliqua scincoides* White), marsupial mice (*Phascogalinae*), and a native cat (*Satanellus hallucatus* Gould). The filling of traps by birds, other than the scrub turkey, is usually accidental.

Crop or stomach contents of some of these species were examined but results, naturally, depend to some extent on the season and environment. The crops of five out of six scrub turkeys trapped near cane were filled with cane fibre and that of the sixth with cane fibre and *Pentatomidae.* Ten bandicoots, when opened up during a dry November, yielded cane fibre; and the stomach of the only blue tongue lizard dissected contained *Sorghum* seeds and adult weevil borers (*Rhabdocnemis obscura* Boisd.).

TRAP BAITS, TRAPS, AND TRAPPING.

Gard (1936) estimated that 277,000 rats were trapped during control operations in the Macknade Mill district during 1934, and in the present work the author has been concerned, over a seven-year period, with the trapping and/or re-trapping of about 40,000 specimens in several mill districts. Whether trapping is undertaken as a direct measure aimed at economic control, as an aid in directing and checking control operations, or for purely research work, the types of traps to be used for the different purposes and the kinds of baits laid therein are of paramount importance.

Trap Baits.

Doty (1938) in discussing the uses of oils as attractants in rat baits in Hawaii confirms Gard's (1935) findings in Queensland that, of the various oils tried, raw linseed oil is the best for this purpose. Gard (*loc. cit.*) also states, "many farmers who were not successful in trapping previously, now use only paper and rag soaked in this oil for bait, and have no trouble in catching rats." The author, on Gard's suggestion at a later date, used small pieces of leather (approximately $\frac{3}{4}$ inch x $\frac{1}{2}$ inch for snap traps) as the trap bait base or carrier for oils.

Carefully controlled field-trapping experiments in different seasons have shown that there is no significant difference in the efficiencies of raw linseed oil, good quality maize oil, or wheat oil, when used on leather. However, linseed oil has two definite advantages: it is cheaper, and trappers usually prefer to work with it than with either of the other two.

Numerous experiments have compared the leather-linseed oil bait with others—such as whole maize, pumpkin seeds, shelled peanuts, coconut and coconut oil, raisins, dried fruits, fresh fruits (banana, apple, and papaw), fruit essences at different concentrations on neutral carriers or bases, bacon, fish (dried and fresh), meat (fresh and salted), bread, split peas, several other vegetable seeds, and cheese. For trapping all indigenous murine species under many different seasonal conditions the leather-linseed oil bait was found to be the most efficient. Where this failed the others did not improve the catch; where the others failed, the use of linseed oil on leather often gave results. This means that for most trapping purposes a standard bait is available and it is one which is convenient for use on a large scale under all field conditions.

For trapping the water rat (*H. chrysogaster*) fresh fish proved the most efficient bait, and the five specimens of the rare water rat (*Xeromys myoides*) taken were caught in "Bureau" traps containing a mixed bait of fresh fish and linseed oil on leather.

In common with experience elsewhere, it has been found difficult, at times, to trap the house rat in buildings without pre-baiting or undertaking other preliminaries; but this is not necessary to the same extent when trapping this species in the field.

Traps.

The essentials of a rat trap for use in the field are efficiency, simplicity and robustness of design, and ease and speed of manipulation. Live trappings for special purposes may be desired; otherwise the rats are caught and killed with the one action, and for this work the ordinary cheap, flat, "snap" or "break-back" trap (Plate 1) has been found most suitable. Before use in the field some

Plate 1.
"Snap" or "Break-back" Traps.

attention should be given to the staples, and when selecting from the numerous brands available only those with a long hook on the tongue (A in Figure 2) should be chosen. For trapping *Uromys caudimaculatus*, and in dealing with large moving populations of *Rattus* species when every trap must be accounted for, the traps should be wired to stakes. Some ingenious safety devices are

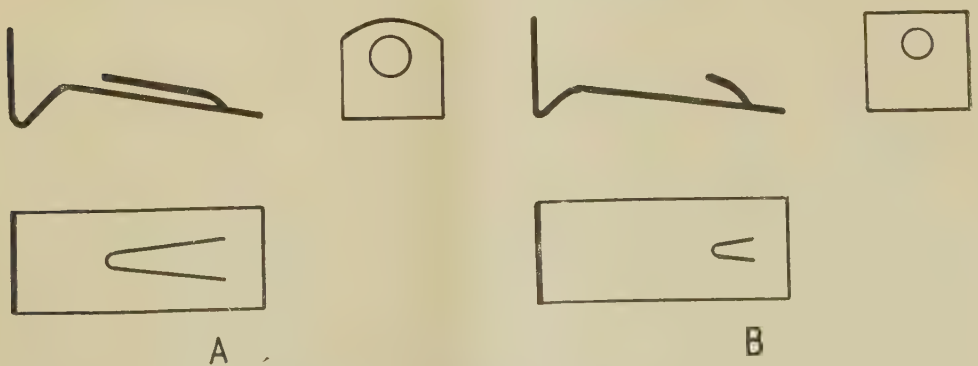

Figure 2.
Two Different Types of Tongue for "Break-back" Traps.

associated with break-back traps but these have been found impracticable for field use; not only do they decrease efficiency and speed of trapping but they have actually proved a danger. The ordinary trap, if firmly held by the back edge, is safe and easy to handle.

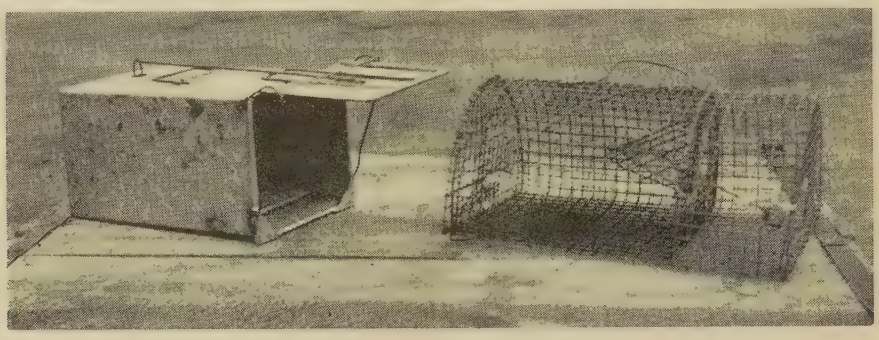

Plate 2.
A Set "Bureau" Trap (left) and a Cage Trap (right).

The cage trap (Plate 2, right), like several other types with automatic action, has little to commend it; it is comparatively inefficient and catches live rats only when large populations are encountered. Even if the idea of automatic traps were sound for practical purposes, their design is usually not sufficiently simple, nor their construction strong enough, for continuous field use.

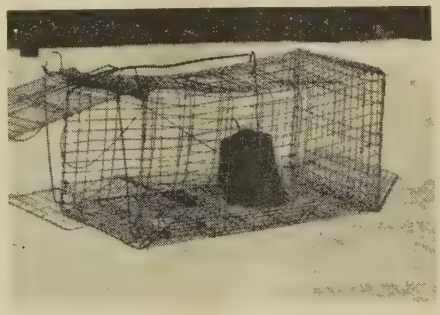

Plate 3.
A Set Wire Trap used for Water Rats.

The wire trap (Plate 3), provided it approximates closely to 8 inches x 7 inches x 14 inches, is best for trapping the water rat.

In rat investigational work a live trap "unit" is often necessary. The trigger release action of these traps usually depends upon the animal touching either the bait or a false floor. Construction details depend upon the habits of the animals to be trapped and the conditions under which the traps are to be used. Chitty (1937) has described and figured the "Tring" trap used at Oxford for small mammals but, for Queensland canefield rat species, a false-floor trap was found to be more efficient; accordingly the "Bureau" trap

(Plates 2 (left) and 4 and Figure 3) was developed. This trap has not only given excellent results as a live trap unit, but it is more efficient than break-backs when collecting rats of many species in small and scattered populations.

Plate 4.
PLACING A SET "BUREAU" TRAP IN POSITION IN A CANEFIELD.

The "Bureau" trap is essentially an adaptation of a wire trap (as in Plate 3) of suitable size, actuated by a false floor. Opaque sides, bottom, and top provide the necessary amount of artificial cover when trapping murine species; an open-work trap is preferable for water rats. The frames of traps used in this investigation were made of 26-gauge galvanized sheet iron and in 1936 a completed trap cost 6s. 6d. Referring to Figure 3: the door lock (h) and the door lock guides (j) must be rigid and 12-gauge high tensile fence wire is suitable; the springs (d and f) are made of medium-gauge piano wire and they are not permanently secured to the frame but attached so that they may be replaced quickly if necessary; two pairs of small holes drilled at (e) and (e^1) for attaching the door spring (f) have given satisfaction. In Queensland canefields bandicoots are fairly common; individuals practically fill a Bureau trap and sometimes damage the springs, spares of which should always be carried by trappers. The edge of the false floor (b) should not be let in to

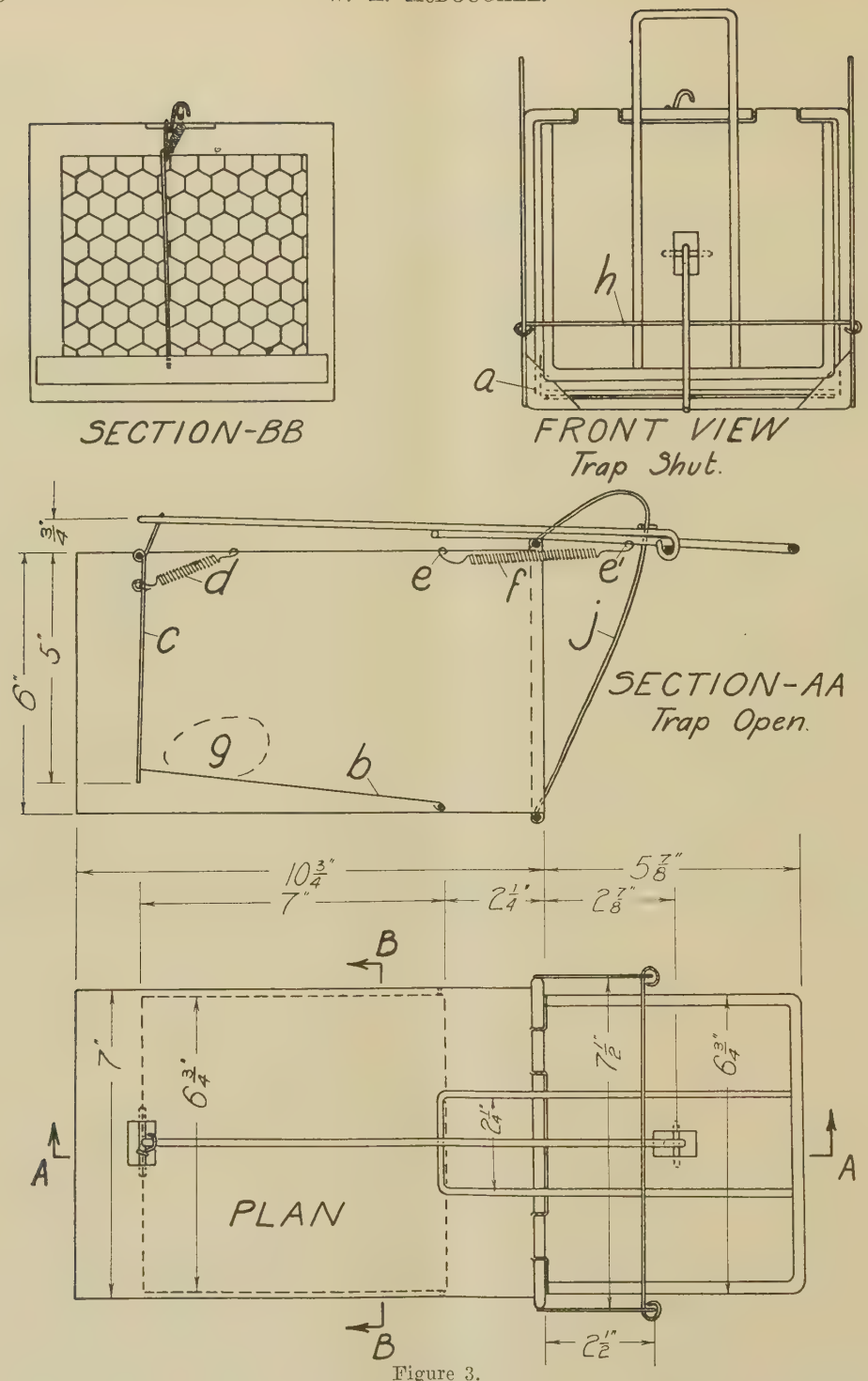

Figure 3.

PLAN OF BUREAU TRAP—(*a*) door stops; (*b*) false floor; (*c*) trigger; (*d*) trigger spring; (*e* and *e*¹) trigger spring contacts; (*f*) door spring; (*g*) bait; (*h*) door lock; (*j*) door lock guides.

a small cut on the trigger (c), as the point of contact of (b) and (c) is responsible for the fineness and flexibility of set; with smooth contact here it is possible to catch very young rats and mice. These traps were used constantly for four years, during which time only minor repairs were necessary, and the chief attention needed was periodical scraping of the false floors and boiling in water for hygienic reasons.

Trapping.

For mechanical reasons it is usually necessary in most environments to chip small patches of ground on which to place traps. This slight disturbance of the soil around and under traps increases efficiency and it has been found a profitable practice even on the bare floor of rain forests.

The wearing of gloves by trappers has no significant effect on catch. It slows down the work and has been practised by the author only as a prophylactic measure when working in swampy habitats.

Some "*conatus*" country is heavily infested by mosquitoes (*Culicidae*) and "sand-flies" (*Chironomidae*). Apparently these pests do not affect rats confined in live traps, but it is impracticable to work such localities without providing protection for the trappers. In this work protection was required for a six to seven hour period, including about four hours of bright, hot sunshine, since all "live" traps, and "dead" traps from which specimens were to be preserved, were cleared before sunrise, *i.e.*, during a time when sand-flies (the worse of the two pests) are very active, and the trap work was usually continued until mid-day. Several protective measures were tried but the only one to give any satisfaction over a number of years was to smear the torso (before putting on a shirt) and all exposed parts of the body with a mixture of equal parts of oil of lavender, citronella, and medicinal paraffin. The legs should be smeared also if not covered by long rubber boots; these were not used unless dew or rain had dampened the ground cover. When working close to the ground clothing is not a complete protection in areas of heavy sand-fly population and sufficient flies to cause inconvenience usually crawl under the clothing.

Preserving Specimens.

Specimens from "dead" traps should be cleared as early as possible and not later than sunrise. After taking the usual measurements, &c., it is essential that, under Queensland coastal conditions, the specimens be immediately gutted, washed, and placed in undiluted methylated spirits.

DESCRIPTIONS AND DISTRIBUTIONS.

Rattus rattus L. (Plate 5).

For present purposes a detailed technical description of this species is unnecessary. Hinton (1931), deliberately omitting mention of colour, briefly describes *R. rattus* thus:

> "Ears large, almost naked and translucent, reaching or covering the eyes when pressed forward. Tail slender, at least as long as, and often considerably longer than,

Plate 5.

Lutra vulgaris (½ natural size).

Plate 6.

Lutra (natural size).

the combined length of the head and body. Pads of soles of feet relatively large. Fur soft, but usually intermixed in adults with many slender grooved bristles, which impart a somewhat harsh quality and bristling appearance to the coat as a whole. The females normally have ten mammae, two pairs on the chest, three pairs towards the groin; in some cases an additional pair, making twelve in all, is present upon the chest. Weight of adults rarely more than 8 oz. (227 grammes) usually less.''

Troughton (quoted by Gard, 1935) comments on *R. rattus* taken from canefields as follows:

''This species is at once distinguished by the combination of the extremely long tail, which, when pressed forward along the back, reached an inch or more beyond the nose-tip, and the coarse and sparse fur. The colour is very variable in any locality, leading to the use of the name *alexandrinus* at times for the light-bellied phase, but the name cannot be applied to the Australian animal; mention of colour in any event seems unimportant when so variable.''

Measurements of a typical male from canefields are:—Head-body, 193 mm.; tail, 218 mm.; foot, 36 mm.; ear, 25 mm.

In sugar districts both light and dark specimens are encountered; the lighter type varies considerably within itself, but the darker is quite distinctive. Occasionally the dark rat is predominant in a field and when traps yield numerous large, well-fed, well-coated specimens, the colour impression of the population is accentuated and results in requests from field workers for check identification.

This cosmopolitan species has been trapped by the author in canefields at Mossman, Hambledon, Gordonvale, South Johnstone, Mourilyan, and Tully (all during July, 1936); the Herbert River district (July, 1936, and September, 1939); and the Mackay district (1936 to 1941). Gard (1935) earlier reported its presence in canefields in the Herbert River district, and between 1936 and 1941 specimens were received from several of the northern cane areas. Incidentally, the only specimens received from a rat-damaged canefield in southern Queensland (Bundaberg, November, 1939) were of *R. rattus*. All specimens taken whilst trapping in rain forest near Tully Falls (Ravenshoe, N.Q.) during July, 1936, were of this species.

Rattus conatus Thomas (Plate 6).

The pertinent points in the type description (Thomas, 1923) are:

''Fur coarse and in old specimens heavily mixed with spinous hairs, a number of finer and longer white-edged piles on the posterior back; ordinary hairs 13-14 mm. in length, longer piles 35-37. General colour above grizzled buffy brown, but in older specimens the blackish spinous hairs are more numerous and dominate the colour, especially the posterior back. Under surface dull whitish, the bases of the hairs slaty. Hands and feet whitish. Tail shorter than head and body and rather well covered with short hairs; black or brownish black throughout; under surface not lighter than the upper; about ten scales to the centimetre. Mammae 3-3, 12.

Skull, on the whole, different from the low skull of *assimilis* or that of the forms with greatly inflated bullae, such as *culmorum* and its allies. Supraorbital ridges well developed running in old specimens to the back of the parietals.

Anteorbital foramina widely open, the plate well projected forward. Palatal foramina narrow extending to the level of the first third of m^1. Bullae rather large.

Dimensions of the type (in the flesh): head and body, 170; tail, 143; hind foot, 29; ear, 22.

Skull: greatest length, 38; condylo-incisive length, 37·5; zygomatic breadth 20; nasals, 14·5; interorbital breadth, 4.7; palatilar length, 19; palatal foramina, 8; length of bullae, 7·8; upper molar row (crowns), 6·9 mm."

The type specimen is evidently an old female, and from its head-body and tail measurements is as large as any of its species likely to be encountered in the field. A series of females of somewhat similar size taken from canefields agree with most of the above measurements, but particularly with those of the skull. They differ, however, in ear length which, in the type, exceeds that of normal large females by about 5 mm. The weights in grammes, and the head-body and tail lengths in millimetres, of six large females selected at random from a fresh field catch were as follows:—132, 168, 120; 161 (pregnant), 174, 125; 146 (pregnant), 168, 123; 162 (pregnant), 170, 130; 147 (pregnant), 172, 124; 128, 170, 123.

The largest male of this species taken in the field by the author weighed 207 g.; the largest of those of which full measurements were made weighed 173 g. and had a head-body length of 185 mm. and a tail length of 128 mm.

In the Mackay district, *i.e.,* in the southern part of the known range, the species is generally darker and none has been taken there with the whitish hands and feet characteristic of the northern specimens. In Mackay specimens these features are sufficiently dark to blend with the general body colour.

The type locality is in the vicinity of Cooktown, North Queensland. Since 1935 this rat has been taken, sometimes in large numbers, in all sugar mill areas from Mossman to the Herbert River district in northern Queensland, and from Proserpine to Mt. Christian (Mackay district) in the central cane districts. No authentic records of its presence in the intermediate Lower Burdekin district are available, and trapping in this area during July, 1936, did not yield this species. Numerous attempts by the author to find this rat on other than coastal lands have failed; habitats on the Atherton Tableland and in the Eungella district apparently suitable for the species were trapped whenever possible, but without result.

Rattus culmorum T. & D.

Extracts from the type description (Thomas and Dollman, 1909) of this species are:

"A coarse or spiny-haired fulvous rat with a whitish belly . . . Size about as in *Mus rattus* [= *Rattus rattus*] or rather smaller. Fur sparse and coarse, more or less mixed with flattened spines. General colour above brownish fulvous, varying considerably according to the degree of spinousness. Sides more buffy. Under surface whitish, often with a tinge of yellow. the hairs pale slaty basally on the belly, whitish throughout on throat and sometimes on the inguinal region. Ears rather short, practically naked. Upper surface of hands and feet white. Tail of

medium length . . . . its rings at base averaging about 10 to the cm., thinly haired; dull brownish; little lighter below. Mammae . . . . 2-3, 10.

Dimensions of the type (measured on the flesh): head and body, 150 mm.; tail, 135; hind foot, 29; ear, 17.

Skull: greatest length 35·5 mm.; basilar length, 30; greatest breadth, 19; length of nasals, 12·2; interorbital breadth, 4·8; palatilar length, 16·7; diastema, 9·7; palatal foramina, 7·5; greatest diameter of bullae, 9; length of upper molar series, 7·1.''

Dimensions of two adult females selected at random from catches in canefields were:

Head-body length.	Tail length.	Foot length.	Ear length.
mm.	mm.	mm.	mm.
145	122	28	16
125	117	27	15

The weights of the heaviest female and male caught by the author in the field were 112 g. and 124 g. respectively.

R. culmorum possesses comparatively large and protruding eyes. This very definite characteristic, which is apparently lost in preserved specimens, is helpful in both field and cage experiments with mixed *Rattus* populations.

This rat has been taken in Queensland canefields in one locality only—viz., Habana (Mackay). Thomas (1909) records it from Heath Island, Beach Mount, and Mt. Abbot—all in the Burdekin district—and recently Finlayson (1942) described and partly figured *R. culmorum cf. culmorum* from near Duaringa, Rockhampton district, Queensland. Troughton (1939) described a subspecies, *culmorum apex,* collected in 1913 at Skull Creek in the extreme north-west of Cape York Peninsula. Iredale and Troughton (1934) list three other subspecies, *c. youngi* Thomas from Moreton Island, South Queensland; *c. vallesius* Thomas from Duck Creek, Macquarie River, and Upper Darling (N.S.W. interior); and *c. austrinus* from Port Lincoln, South Australia.

Rattus assimilis Gould.

This more widely known species is described in ''The Wild Animals of Australasia'' (Le Souef *et al,* 1926) as:

''Fur long, soft, extremely thick on back; slate-coloured fur tipped with light brown; bases of longer hair greenish grey to length of fur, remainder either wholly black or tipped with light brown, producing pencilled effect. They are brightly irridescent in sunlight; sides lighter, merging into greyish-buff colour on under surface, which is produced by lighter slate colour of basal fur with its dull white tips. Feet covered with fine silvery-white hairs. Ears laid forward reach little beyond posterior margin of eye. Pinna thin, covered sparsely but evenly with light brown hairs externally, and with silvery to light brown hairs internally. Tail thinly covered with dark brown hairs, with lighter tips, which generally are longer than scales. Head and body, 180 mm.; tail, 160 mm.; hind foot, 37 mm.''

The measurements of a medium-sized female selected at random from an *assimilis* population in and near canefields were:—Head-body, 150 mm.; tail, 130 mm.; foot, 34 mm.; ear, 17 mm.

Brazenor (1936) when describing an average Victorian specimen found the tail uniformly brown, but most *assimilis* taken by the author in Queensland coastal areas have had distinctly cream-coloured tail scales. Topotypes (Atherton Tableland, 1936) of *assimilis coracius* Thomas were found to have much darker tails than the coastal specimens.

The tympanic bullae are convenient internal characters for separating the three indigenous *Rattus* species associated with cane in central and northern Queensland. With *assimilis* exhibiting the smallest and *culmorum* the largest, these structures show a graded increase in size of tympanic bullae from species to species (see Plate 7).

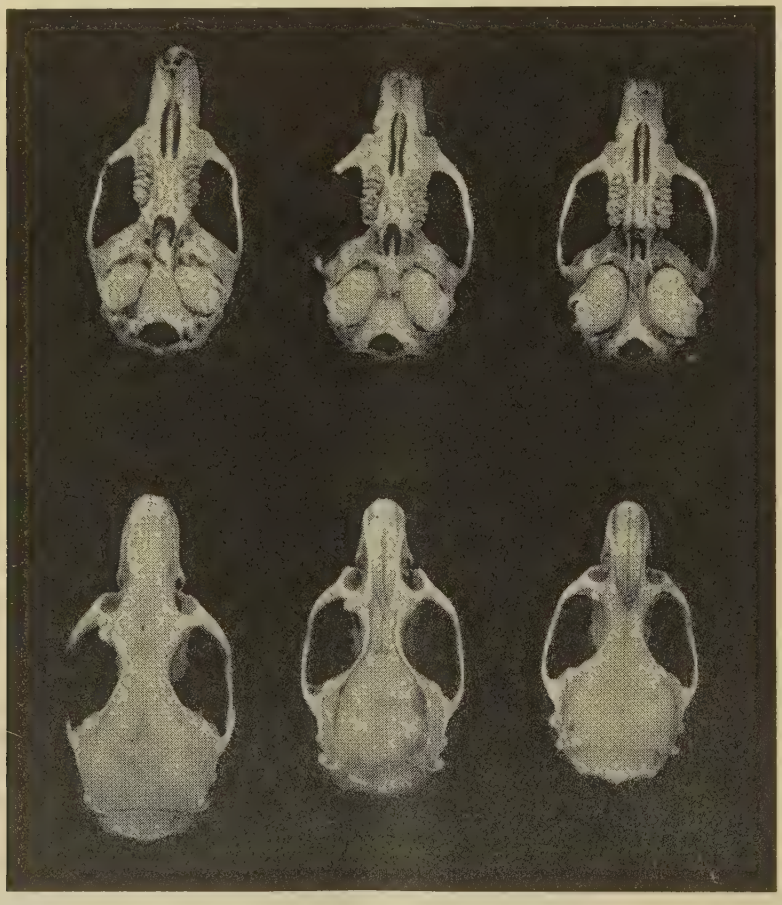

Plate 7.

VENTRAL AND DORSAL ASPECTS OF THE SKULLS OF (from left to right) *Rattus assimilis*, *R. conatus*, and *R. culmorum*.—Note the graded increase, from species to species, in the inflation of the tympanic bullae.

Plate 8.
Melomys littoralis (¾ natural size).

This species has been taken by the author in or near canefields at Abergowrie (July, 1936); Gordonvale (July, 1936); and South Johnstone (September, 1939); and a number of specimens from Mourilyan canefields (Mr. E. H. Fox) were received during 1938-39. Iredale and Troughton (1934), Derrick *et al* (1940) and Troughton (1941) indicate that the range of this species is coastal and mountainous regions of eastern Australia.

Melomys littoralis Lönnberg
(Plate 8).

Lönnberg (in Lönnberg and Mjoberg, 1916) in his type description of this species states:—

> "This rat is probably related to *M. cervinipes* of which it may be a dwarfed littoral race. It differs, however, very plainly in being much smaller and slenderer in every respect. . . . .
>
> "The general colour is on the sides most similar to Ridgway's 'drab,' somewhat suffused with buffish, on the back darker, more brown by means of the blackish-brown tips of the hairs. On the flanks the colour of the lateral parts pass gradually into the light buff of the lower side. . . . . The throat is yellowish-white. The feet are scantily covered with whitish hairs. Tail wholly dark. The fur is soft and dense, about 11 mm. long; basally it is slate grey on the upper side, plumbeous grey on the lower side. The scales of the tail rather small so that 18-19 rings may be counted to the centimetre.
>
> "Head and body (skin) about 90 mm.; tail a little longer, about 112 mm. Hind foot dry (s.u.), 26 mm., c.u. 27·8 mm. Greatest length of skull 30·2 mm.; condylo-incisive length, 28; zygomatic breadth, 15; nasals, 10·5; interorbital breadth, 4·7; mastoid breadth, 11·9; palatal length to include incisors, 13·5; palatal foramina, 4·8; upper molar series, 6·1."

Measurements of three *littoralis* specimens taken at random for head-body, tail, and hind foot were as follows:—Female, 114 mm., 117 mm., 24 mm.; male, 115 mm., 131 mm., 24 mm.; male, 122 mm., 127 mm., 27 mm. The skull

measurements of the last-mentioned were:—Greatest length, 30 mm.; condylo-incisive length, 27·4 mm.; zygomatic breadth, 15·1 mm.; nasals, 10·2 mm.; interorbital breadth, 4·1 mm.; palatilar length, 13·2 mm.; breadth of brain case, 13 mm.; palatal foramina, 4·9 mm.; upper molar series, 5·7 mm. Adult weights usually range from 30 g. to 50 g., but the male of two specimens somewhat darker than usual, and taken in a swamp, weighed 60 g.

In 1935 Troughton (*loc. cit.*) remarked that "this . . . . species of coastal north Queensland has hitherto been known only from the original female and young collected near . . . . Russell River [Babinda Mill area] . . . . and the subspecies from Hinchinbrook Island, *M. littoralis insulae*, described by Troughton and Le Souef in 1929." Since then, *littoralis* has been found to be widely distributed in all sugar-cane areas north of, and including, the Mackay district.

Melomys cervinipes Gould.

Gould's original description of *cervinipes* is not available to the author, but the Director of the Australian Museum has supplied the following extract and notes:

> "Distinguishing characters are: its short, soft adpressed, furry coat, destitute of any lengthened hairs along the back and sides of the body . . . . the nearly uniform rufous colouring of its upper surface . . . . and its slender hairless reticulate tail. Head, all the upper surface and flanks sandy brown, the base of the fur being dark slaty-grey; tarsi and feet fawn colour; undersurface variable buffy white and grey, the base of the fur being grey, and the extremity buffy white; tail purplish flesh colour. In some, the buffy white (of the belly) predominates and becomes conspicuous on the throat and breast. In young animals the upper surface is bluish grey and the under surface greyish white. Dimensions were not originally given by Gould."

In "The Wild Animals of Australasia" (Le Souef *et al*, 1926) the dimensions of *cervinipes* are given as:—Head and body, 150 mm.; tail, 145 mm.; hind foot, 32 mm.

Corresponding measurements of three adult specimens selected at random from canefield catches were:—Male, 127 mm., 142 mm., 28 mm.; females, 118 mm., 140 mm., 27 mm.; male, 140 mm., 153 mm., 28 mm. The skull measurements of the last-mentioned were:—Greatest length, 35·3 mm.; condylo-incisive length, 32·2 mm.; zygomatic breadth, 18·7 mm.; nasals, 11·5 mm.; interorbital breadth, 5·3 mm.; palatilar length, 15·5 mm.; breath of brain case, 14·2 mm.; palatal foramina, 6 mm.; upper molar series, 6·5 mm. Adult weights usually range from 40 g. to 60 g.; the largest male taken in the field weighed 73 g., and a male in captivity reached 95 g.

The tail scale count was found to be of little use in separating the two *Melomys* species taken in canefields and both have three hairs per tail scale. The dorsal muzzle line of *cervinipes* exhibits a slight hump, which gives living specimens of the species a facial expression quite distinct from that of *littoralis*. In addition to the blue-grey colour of the young cited above, the comparatively large feet of young *cervinipes* can be used to advantage as a distinguishing

feature; a *littoralis* of similar body size is of lighter build and reddish-khaki. In many instances habitat differences (see pages 73-76) help in separating these species in the field.

The type locality of *cervinipes* is Stradbroke Island, Moreton Bay, South Queensland, and its range is given (Troughton and Le Souef, 1929) as New South Wales and South Queensland. *M. c. eboreus* Thomas is described from Ravenshoe, North Queensland, and *M. c. pallidus* Troughton and Le Souef from Hinchinbrook Island, North Queensland.

The distribution of this species in cane districts is not fully known; it is suspected that, in suitable seasons, its occurrence is wider than records indicate.

Difficulties with the identification of *Melomys* species in canefields followed the collection of field data over a number of years. These difficulties were initiated during 1934-36 as, early in this period, *littoralis* had been identified as associated with damage to sugar cane in the Herbert River district where, prior to 1935, most of the detailed observations on cane pest rats had been carried out. With the widening interest in the subject (McDougall, 1944) the identifications from the one district were used in others where, in some instances, different ecological conditions occurred. Also, during the period 1933-36 large or diminishing rat populations, abnormally dispersed, were encountered, and these contained a large percentage of immature animals. This undoubtedly created difficulties in separating poorly known species of a difficult genus, since, to field workers, size is a useful specific characteristic. In later years, when rat populations became stabilized and more normal, the separation of *littoralis* and *cervinipes* was easier. During 1939, after separating the species, samples of *Melomys* catches of earlier years were checked and in a number of instances the rats from canefields in different mill areas were found to be *cervinipes* and not *littoralis* as previously identified.

M. cervinipes has been trapped in canefields at Mt. Jukes, Sarina, Cattle Creek, Habana, and Macquarie Creek (all in the Mackay district) from 1936 to 1940; South Johnstone (August, 1939); Mossman (July, 1936); and Gordonvale (July, 1936). Mr. E. H. Fox supplied specimens from the Mourilyan Mill area during 1938 and 1939.

During the winter months of 1936-38 *cervinipes* was trapped at Eungella and Mt. Dalrymple, both places situated in mountainous country, about 45 miles west of Mackay.

When investigating rat damage to reforestation projects at Imbil, South Queensland, Mr. R. H. Doggrell submitted, in 1936, a collection including this species as well as *R. assimilis* Gould and *R. lutreolus imbil* (identified and described by Troughton, 1937).

Hydromys chrysogaster reginae T. & D.

Le Souef *et al* (1926) records this species as being:

"General colour dark greyish, slightly darker along dorsal line; under surface white tinged with buff; tail black, white terminally. Head and body, 336 mm.; tail, 320 mm.; hind foot, 66 mm.; ear, 19 mm."

The numerous geographic races of this water rat have a wide range over eastern Australia. *H. c. reginae* (type locality, Inkerman) is present in all central and northern sugar-cane districts. A water rat taken by the author at Ravenshoe (Atherton Tableland, 1936) has been identified by Mr. Troughton as the topotypical *Hydromys longmani* Thomas.

Xeromys myoides Thomas.

"External appearance very like ordinary rat. Fur very short.. General colour above dark slaty grey; under surface white. Ears short and rounded; laid forward they do not reach to within 3 or 4 mm. of posterior canthus of eye. Hands and feet very thinly haired; white. Palms and soles naked, former with five, latter with six, pads; last hind-pad elongate. Tail slender, scaly, covered with fine white hairs. Head and body, 110 mm.; tail, 154 mm.; hind foot, 40 mm.; ear, 20 mm."

(From "The Wild Animals of Australasia," Le Souef *et al*, 1926.)

Dimensions of specimens taken by us do not agree with those given above; measurements of these specimens were:—Female: Head-body, 120 mm.; tail, 87 mm.; hind foot, 23 mm.; ear, 10 mm. Male: 129 mm.; 86 mm.; 25 mm.; and 10 m.m.

This rare water rat has been reported from the Mackay district only, and the specimens were trapped with *H. chrysogaster, M. littoralis,* and *R. conatus* in a "reed" swamp close to canefields about 12 miles from Mackay.

Uromys caudimaculatus Krefft.

This large mosaic-tailed rat is briefly described in "The Wild Animals of Australasia," under the name *U. macropus,* as follows:—

"Fur moderately soft, but longer hairs rather bristly. General colour above greyish brown, tinged with reddish, some coarse black-tipped hairs intermixed; under surface white. Whiskers very long, stiff, black. Feet white. Tail black on basal part, white or pale yellow on apical half. Head and body, 363 mm.; tail, 360 mm."

A somewhat smaller specimen (female) taken by the author measured:—Head-body, 260 mm.; tail, 330 mm.; foot, 61 mm.; ear, 27 mm. This species was trapped in large numbers at Abergowrie (Herbert River district) during June, 1936, and in the same month at Gordonvale. It is apparently a coastal species, with Cardwell as the known mainland southern limit of its range. The type locality is recorded (Iredale and Troughton, 1934) as Cape York, North Queensland, and Sawers (1938) lists a specimen from the Cairns district.

Thetomys gracilicaudatus ultra Troughton.

Troughton (1939) describes this subspecies as:

"General coloration above speckled yellowish-brown, composed of the clay and dark mummy brown tipping, the light tips becoming paler on the head, rump, and

sides where an ochraceous-buffy wash is indicated. Basal fur about deep neutral grey, contrasting with the yellowish-brown tipping of the back . . . . Dimensions of of holotype: . . . . head and body 110; tail 105; pes 26; ear 16 mm."

The largest male of this species taken in the field by the author weighed 66 g. As in all known indigenous mice there are no pectoral mammae, the formula being 0-2, 4. This species has been trapped only in a few localities near Habana (Mackay district). *T. gracilicaudatus* Gould has been reported (Iredale and Troughton, 1934; Troughton, 1939) only from South Queensland (type locality—Oak Creek, Darling Downs).

Mus musculus Linné.

This imported mouse may be easily distinguished from the native species by the notched wearing surface of the upper incisors and the presence of ten mammae (3-2 = 10). Brazenor (1936) gives the dimensions as:—"Head and body, 74 mm.; tail, 82 mm.; hind foot, 17·5 mm.; and ear, 11·5 mm." The general colour is variable from dusky grey to yellowish brown; those taken in canefields often have the hair tips bleached, whilst specimens from houses, rubbish dumps, and thick protective ground cover (*e.g.*, a heavy stand of *Mimosa pudica*) are darker.

Gard (1935) reported the presence of mice in the Herbert River canefields, and the author has trapped *M. musculus* in canefields at Tully (July, 1936), at Gordonvale (July, 1936), and in the Mackay district (1936-40).

GENERAL HABITS AND STATUS OF SPECIES AS PESTS IN CANE FIELDS.

Rattus rattus L.

Pemberton (1925) and Gard (1935) have reported the house rat as nesting in trees. Cilento (1936) illustrates rat nests in trees in the Herbert River district, and although in the accompanying text no attempt is made to distinguish the nesting habits of various species, it is obvious that these nests are those of *R. rattus*. Poorly constructed nests of this species—in the form of shallow depressions in the soil and lined with grass, cane trash, or other bedding—may be found at the bases of cane stools and clumps of Guinea grass (*Panicum maximum* Jacq.). The wide variation in the quality of the nests of this species in the field is paralleled in and around buildings.

Gard (1935) considers this rat of small economic importance in Herbert River canefields, attacking cane only close to buildings. The author has trapped it in widely-separated canefields and sometimes in large numbers, but the damage to cane caused by it is usually insignificant and mostly of slight nuisance quality. On occasions heavier rat damage in house rat infested fields has been noticed, but trapping and other signs have indicated that one of the native rats—usually the small khaki rat—is the responsible agent. Conditions in the Te Kowai-Racecourse (Mackay) area during 1936 can be quoted as an example. During

the winter it was difficult to trap other murine species around the lagoons because house rats filled the traps. There were numerous complaints about rats in buildings; a fernery was attacked, and biscuits and other groceries had to be protected. Large house rat populations were encountered in canefields and, when a quarter of an acre of Guinea grass was burnt off, 227 house rats were counted leaving the fired area. A few patches of cane were attacked by rats, but in all instances either the field rat or the small khaki rat was present.

The bite of the house rat in cane is usually distinctive and is more uneven and ragged than those inflicted by the native species.

In all sugar-cane districts it has been observed that, at times, rats enter dwellings and other buildings from the fields. This usually happens towards the end of harvesting, and often the cane immediately adjacent to the entered buildings has not suffered from rat attacks. The house rat is the only *Rattus* species known to enter buildings from canefields and other vegetation and is, therefore, the only rat frequently associated with both houses and canefields.

The house rat seldom attacks stored sugar, *i.e.*, sugar stacked in bags. However, in poorly constructed and secluded stacks some damage has been noticed, but it was evident that the rats desired the bag shreds for bedding and nesting material rather than the sugar for food.

Rattus conatus Thomas.

Plate 9.
OPENINGS OF *R. conatus* BURROWS IN AN IRRIGATION BANK, TE KOWAI, MACKAY.

This rat is a burrower (Plate 9), and one of the simplest forms of a colony is a single well-established nesting burrow consisting, primarily, of a tunnel two to four inches in diameter and sloping from ground level to a nest

chamber. The nest is fairly compact, rounded, about six inches in diameter, and made of dry grass and/or cane trash or other similar plant material. From the main tunnel and/or the nest chamber there may be subsidiary tunnels of varying length, diameter, destination, and degree of branching. Many of these are blind, but at least one is carried to the surface to make another colony burrow opening. There are no main entrances or exits from a colony, and any opening may be used for either purpose. Some of the subsidiary tunnels are as long as 20 feet on ground plan, and they turn and twist, sometimes break soil surface here and there, connect with each other, and often do not exceed one inch in diameter. It is impracticable to dig out these burrows in most soils without first inserting a flexible stick in each successive straight portion; otherwise they may be lost. A similar system may be found without the nest, and the expanded tunnel or chamber is then used as the chief living chamber. Other burrows may not have progressed as far as the excavation of a chamber, and these, called "travelling" burrows, are used by the rat or rats for a short time before moving elsewhere. Bandicoots, when searching for grubs or other food, often dig holes superficially resembling rat burrows, but probing with a stout stick will show that only rat burrows, if advanced at all, have turnings. A network of runways or pads, with those from the burrow openings in use as main stems, are associated with a colony. Often the main runways are easily seen, particularly in soft, wet, or sandy soils, and when a number of active rats are in residence. Sometimes loose dirt is noticeable at burrow openings, but mounds cannot be associated with this species. Tunnels to a depth of three feet have been traced, but usually most of the burrow system is within 15 inches of the ground surface.

An advance upon the single nest or living-chamber colony is the multiple one extending over larger areas and consisting of the three types of burrow, either in use or abandoned. As an example, it may be noted that at Abergowrie, during July, 1936, 1,051 burrow openings (in use) were counted in an area 19 yards by 142½ yards and, in addition, openings apparently not in use were estimated at 2,300. A continuation of this narrow strip for another 80 yards yielded a further 216 openings in use, but in the lower country for about 200 yards around only a few scattered openings, at the rate of five to the acre, were to be found. Taking this field as a whole the burrow distribution is typical of any infested area arbitrarily defined and without due recognition of the natural habitat of the species.

In a colony area the runways and tunnels from each unit system may intermingle; sometimes undermining is appreciable, and when crossing rat-infested sandy country, either on foot or on horseback, sinking underfoot may be experienced. In canefields there is a tendency for much of the tunnelling to follow the cane lines, with the nests under, and burrow openings at the bases of, stools. This is particularly noticeable in well-hilled cane in damp fields; in uncultivated lands burrow openings are often found near clumps of grass, stumps, fence posts, and large stones.

Whilst young are nest-bound all males and females without young are kept away as far as possible, and they are forced to live and sleep in parts of

the colony not in immediate contact with the nest. During non-breeding periods an isolated single living-chamber (which may be an old nest) burrow system may harbour a number of rats; one dug out contained 23 specimens.

The desirable natural living conditions for *R. conatus* are a damp friable soil capable of, and actually providing, close and substantial ground cover, often termed harbourage. As pointed out by Gard (1935) the presence of water near the burrows is not essential. In dormitory cages where dry food is provided these rats drink from drip water bottles, but a colony of *conatus* lived for three years in a field cage on forest soil, where the only water available was that provided either by rainfall or by light hosing sufficient to keep Guinea grass ground cover flourishing. In the field large numbers of these rats may be found during dry periods some miles away from free water.

This species has not been taken by the author in rain forest, although many attempts, using both line and grid trapping, have been made. Some grids and trap lines have been placed partly in cane or grass and partly in rain forest and where, apart from the ground cover, environmental conditions were similar, but the field rat was taken only in the cane or grass. Also, parallel trap lines, some set in rain forest and others set through ground cover adjacent to the forest edge, have never yielded this species in the forest lines. Similarly, vegetation such as lantana (*Lantana camara* L.) in a pure stand is not sufficiently close to the ground to harbour *conatus*. A complete list of cover species is merely that of plants of suitable growth in any district and growing in the particular soil conditions favoured by the field rat. Some of the more common are: blady grass (*Imperata cylindrica var. Koenigii*, R. & S.), Para grass or giant couch (*Brachiaria purpurascens* Raddi), sensitive plant (*Mimosa pudica* L.), Guinea grass (*Panicum maximum* Jacq.), native and cultivated sorghums (*Sorghum* spp.), green manure or cover crops (*Vigna spp.*), sugar-cane (*Saccharum* spp.), goat weed (*Ageratum conyzoides* L.), and red Natal grass (*Rhynchelytrum repens* C. E. Hubbard). Despite occasional instances of cannibalism the diet of the field rat is essentially vegetarian, and consists of the stem tissues and seeds, where possible, of the harbourage. Often the cover is not a pure stand of any one species but includes other plants which, by themselves, would not provide suitable ground cover, but which do provide food and are sometimes attacked before or in preference to the main or obvious cover species. As an example it is recorded that small tufts of couch grass (*Cynodon dactylon* Pers.) growing near or amongst taller cover are often eaten first. Similarly Gard (1935) reports the seeds of the noogoora burr (*Xanthium pungens* Wallr.) to be eaten by the field rat.

Sugar cane is often considered an accidental addition to the diet, and this is equally true of any other plant attacked by this rat. Cover plants are part of the desired environment, and the part providing food, but so far as *conatus* population distribution is concerned, field evidence has not demonstrated preference for any particular food plant sufficient to override the conjunctive factor of soil environmental conditions. As an example, the lower slopes of a gap in the Habana district contained a number of seepages, some virtually

permanent and others intermittent, and were planted to cane and other crops. Over a period of three years an area on these slopes, approximately 15 chains wide by three miles long, was under observation and trapping. The field rat was definitely associated with these seepages irrespective of their cover crops. One seepage covered a small part of a field of cane, and rats were present only in this small part; another partially occupied an area planted to cowpea, a third to a portion of a saccharine sorghum plot, and a fourth occurred in blady grass, but only the seepage areas yielded rats. For two years another of these wet spots (a small part of a large field) was covered successively by grass, Poona pea, and then sugar cane, but under these different covers rats were invariably trapped in numbers only in the damp portion of the field.

Compared with the house rat, the field rat is clumsy and when ploughed out it attempts, with a hopping gait, to escape. On ploughed ground it is easily caught or killed with a stick, but if released in its undisturbed natural habitat it quickly disappears by trotting or creeping and by taking every advantage of cover. Being a poor climber it feeds from the ground or other substantial foundation, and in canefields the stalks, if not sprawling or lodged, are first felled by attack on the lower internodes; bites on higher internodes are effected later. Occasionally young rats may climb up leaning stalks to feed, but usually the attack on cane by a pure *conatus* population is indicated by the presence of burrows and of bites capable only of being inflicted from the ground.

Small food is masticated and swallowed direct, but large pieces, such as splinters of cane or maize seeds, are held with the front feet and quickly nibbled away while the animal sits on its haunches after the style of a squirrel. This species may feed gregariously, but if a quantity of food is moveable it may be taken away for a meal in solitude. Like some other species of rats it may return to the same food supply each night, but the creating of its own accord of a definite feeding place is not so highly developed as in, for example, some house rats and water rats. Unlike some of the field rats in rice fields in India (Wagle, 1927) and other rodents, *conatus* does not store food in its burrows, and any material taken there is for nest-building purposes. The same habit is characteristic of the house rat, although it is easier to demonstrate with the latter species. On several occasions the packeted, thallous sulphate-treated, wheat baits used in canefields were laid in buildings; the rat population was apparently reduced, and the bait "take" was good. Later many of the baits were found in nests as bedding, and in some of these nests, kept under discreet observation, families were reared and dispersed.

Sick field rats and a few individuals of large congested populations have been noticed above ground in the day time during cloudy and dull weather, and once, during a sunny day, a hawk was seen to dive and pick up a rat from a known field rat colony area. Normal out-of-burrow activities, however, are nocturnal; and at night, in canefields being attacked by this pest, gnawing and cracking of cane and the squeaking of the rats can be heard. In dormitory cages there is a noticeable increase in activity late in the afternoon.

Mating, playing, searching for food, and feeding are carried on by rats of this species intermittently during waking hours; they urinate indiscriminately and without assuming any particular posture, and urine and faecal pellets are to be found even amongst their food. The home ranges of rats in bulk have an appreciable odour, and canefields occupied by large populations soon assume a distinctive stench, which is accentuated by damp conditions.

The field rat, *per capita,* is not so severe a destructive agent of sugar cane as are the *Melomys* species. However, in some seasons large populations attack canefields, affecting extensive areas in suitable environmental conditions, and then true economic damage is comparatively high; this is due simply to mass attack. In other seasons the area of cane attacked is often negligible, and most of the damage is of the nuisance type only. The ability of this species to sustain mass attacks places it first in importance as an economic rat pest of cane. Further, Sawers (1938), in discussing the leptospirosis problem in Australia, considers *R. conatus,* then incorrectly called *R. culmorum,* the main reservoir of infection in Queensland canefields.

Rattus culmorum T. & D.

This species is a burrower which builds a distinct ridge of soil around the main burrow openings, whilst those formed by *conatus* in the same soil type are more often level with the surroundings. In principle the simple burrow system is similar to that of the field rat, but tunnelling is not so extensive, and in canefields there is not the tendency to nest under stools that is shown by *conatus.*

During a visit to the Lower Burdekin district an attempt was made to inspect the type localities of this species, but it was found that Beach Mount and Heath Island could not be approached from the landward side; evidently the original specimens from these localities were taken from the grassy, sandy places amongst mangrove creeks and marine swamps. In the Habana section of the Mackay district cane growing in a similar situation, *i.e.,* in sandy soil with a constantly high water table (and in this case also amongst mangrove creeks and marine swamps), was attacked by field rats and small khaki rats during 1935 and 1936. During 1937 *R. culmorum* appeared in numbers, and in 1938 it became the predominant species, but in succeeding years all rats disappeared from these particular fields. Whilst trapping *conatus* in damp localities in the more typical forest country on the same farm, the owner remarked that on the sandy soil a brown rat which had been observed in previous years was also present. The check-up resulted, as above, in the finding of *culmorum,* and over a number of years of trapping on this and adjacent farms only an occasional brown field rat was taken at a distance (sometimes as far as two miles) from its habitat. These strays, as with other species when trap lines were taken through unlikely rat country, were usually old males.

Apparently *culmorum* can damage cane near or in its own environment, which, however is limited as far as cane land is concerned. This smaller *Rattus*

species is, *per capita*, less severe on cane than *conatus*, but its method of attack is the same, *i.e.*, primarily from the ground.

Rattus assimilis Gould.

Brazenor (1936) in discussing *assimilis* remarks:

> "This . . . . rat is an inconspicuous completely nocturnal animal. It prefers a habitat in thick scrub and makes its burrows under overhanging branches of bushes, under logs, or at the base of thick grass clumps. As a rule the burrows are not deep; they slope gently down to an enlarged chamber in which is a nest of grass . . . . This rat leaves no noticeable tracks, for its runs seldom extend far from the mouth of its burrow and have not a well-used appearance."

With due allowance for cover differences, this species has living habits somewhat similar to the field rat. *R. assimilis* has been taken by the author only in rain forest and adjacent canefields and, compared with the populations of other rats in cane, it is encountered in small numbers only and seldom more than 50 yards from its native habitat. When *assimilis* has been found in cane *M. cervinipes* has also been present, but in numerous fields the only scrub rat which could be trapped was *cervinipes*. On several occasions, with converging environments, the field rat, the scrub rat, and the large and small khaki rats have been present in fields at the same time.

In a personal communication received during 1937 Mr. Brazenor described damage inflicted by indigenous rat species on pine tree reforestation in the midst of virgin scrub in Victoria. Both *R. assimilis* and *R. lutreolus* were involved, and it is of interest to note that the same two species were included (see p. 65) in a collection of rats associated (at least to the extent of having been trapped near at hand) with damage to forestry projects in South Queensland during 1936. In this instance Mr. Doggrell noticed an *assimilis* specimen in cleared country about 200 yards from standing scrub.

Although cane fibre usually predominates in the stomach contents of those *assimilis* specimens taken in canefields, it is considered that this rat is of little economic importance as a pest in cane. The species should be recognised, however, in the interpretation of ecological data; for it is evident that in the past the group *R. assimilis-M. cervinipes* has sometimes been considered as *R. conatus-M. littoralis*, chiefly on the false assumption that *cervinipes* and *littoralis* are conspecific.

Melomys littoralis Lönn.

This agile rat spends much of its time off the ground and builds somewhat spherical nests of grass, cane trash, or other dead leaves (Plates 10 and 11). As stated by Gard (1935), each nest has two openings, and varies up to eight inches in diameter. Troughton and Le Souef (1929), in discussing *M. l. insulae*, remark that "The specimens were taken only adjacent to some high grass, known as 'blady grass,' about 3-4 feet high, in which they built nests fairly well up amongst the stems; the nests were circular, about 5 in. in diameter, and of similar size to a blue wren's nest." In cane or tall grass the nests are usually

one to three feet from the ground, but some have been found as high as six feet. Irrespective of cover (which may be Pandanus, other palms and shrubs, as well as sugar cane and grasses), every effort is made by these rats to conceal their nests. Gard (1935) reports that "the tree rat nests above ground as a rule .... although in several instances it has been found in burrows beneath the ground."

Plate 10.

Melomys littoralis NEST IN PANDANUS.
(Photograph from K. R. Gard.)

Plate 11.

Melomys littoralis NEST IN SUGAR CANE.
(Photograph from K. R. Gard.)

Lönnberg (1916), in dealing with the type specimen (a female with two young taken under a board on a beach), notes that "the two young remained attached to the teats although the mother ran hither and thither on the beach for a while before she was caught. . . ." It is usual for these rats to leave their nests when an intruder touches, or in many instances merely approaches, them; and, if the young are being suckled, they remain attached to the teats. A mother carrying as many as four young of a total weight larger than her own may be seen struggling amongst cane foliage or along the ground, but if small young are being carried movement is rapid. Her object is to get away from disturbance as quickly as possible, and sometimes, under such circumstances, the haven may be a hole in the ground, a ground-rat burrow, or shelter under a log, but these situations are not used for nesting purposes. This vacating of nests makes it difficult to study nesting habits in the field. The presence of abandoned young is positive evidence that the nest is in use, otherwise this fact has to be decided on appearance and internal evidence such as temperature and cleanliness. No more than one adult has been seen leaving any nest. In captivity, each breeding female invariably constructed her rounded nest with the wood wool provided in all cages. With the sexes segregated there is still a tendency for each female to

make a nest for herself, but in some instances up to four have occupied one nest for months at a time. In cages males will use nests built and abandoned by females, but generally they use the wood wool merely as cover; in the field, males have not been seen emerging from, and have not been trapped in, nests being used by breeding females. The resting places or sleeping quarters of males in breeding cages may assume the appearance of a crudely built nest, but this is due to constant use rather than to any attempt at building.

In many instances *littoralis* and *conatus* are associated both in canefields and other environments, and the ground cover necessary for the field rat is often suitable for the small khaki rat; sugar cane and blady grass are typical examples. However, soil condition, a limiting factor in *conatus* dispersal, does not concern *littoralis* other than indirectly through its effect on plant life, and this latter species may be found in comparatively large numbers in "palm tree" swamps, which are fairly common in northern cane districts, and country supporting a mixture, sometimes sparse, of grasses and shrubs. These covers supply suitable hiding places for nests, some protection for the rats themselves, and allow greater freedom of movement than is desired, say, by *conatus*, or is possible in some types of close ground cover inhabited by the ground rat.

M. littoralis is more of a wanderer than any of the native *Rattus* species associated with canefields, but it has never been taken by the author in rain forest. When breeding these rats may be found up to 60 yards from their nests and, at other times, either complete or partial changes of range may be frequent; these may be sudden following interference or local disturbance. Damage to sugar cane by this rat is often patchy, and when investigating quite fresh rat bites it may be found that the rat or rats responsible have moved elsewhere or, at least, have not returned to feed at or near the same place. Rats of this species will enter houses and other human habitations near their native habitats, but such trespass is mostly casual and in keeping with the general habits. *M. littoralis* is a vegetarian and its habits allow it a diet more varied than that of the field ground rat. In addition to plant tissues such as sugar cane and the soft barks of shrubs, &c. it eats berries and other native fruits, guavas (*Psidium guajava* L.), and sometimes the cultivated banana (*Musa* spp.); stomach contents are generally more liquid than those of the *Rattus* species. In canefields, their neat bites, surrounded by typical teeth marks in all but very soft varieties are found up the stalks; but this does not mean that *littoralis* climbs an erect stalk, clings on, and eats. Usually a slanting or crossing stalk or trash serves as a platform during feeding, and this is well illustrated in some fields of mixed varieties. For example, in two fields, one of Q.2 and H.Q.426 and the other of Q.2 and varieties with similar rind hardness, all except Q.2, the only erect self-trashing variety present, had been attacked by this pest. On another occasion three pieces of trash well up the stalks in a Q.2 field had failed to fall and above each was a *littoralis* bite.

As a pest of cane this species is, on present knowledge, second in importance to the field rat. Often it attacks cane six to eight weeks earlier than *conatus*,

and in some years it is responsible for most of the rat attacks on cane in many Queensland cane districts, when the greater proportion of the effect is of a nuisance order only. This rat is itself capable of causing, and does cause, economic damage to cane, but its chief role is in conjunction with *conatus;* it may be responsible for converting nuisance damage into economic losses or for unduly aggravating the position in fields where losses were already appreciable.

Melomys cervinipes Gould.

Little is known of the nesting habits of this species, and reports of its building in such likely places as vines, stumps, and trees have not been confirmed. In captivity it does not build rounded nests similar to those of the small khaki rat, but is content with a poorly made bed and wood wool as cover; it should be pointed out, however, that this rat has not been bred in captivity. It has many characteristics similar to those of *littoralis*—such as varied diet, agility, wandering, leaving teeth marks around its bites in cane, and attacking cane well up the stalks—but damage inflicted by it is much more severe than that of the smaller rat.

The native habitat of *cervinipes* is rain forest, where it has been trapped over extensive areas; and, although it damages cane adjacent to scrub only, occasional specimens have been taken in cane up to 200 yards from the edge of the scrub.

The status of this species as a pest of cane is at present indefinite, as its true distribution in cane areas in years of heavy rat population is not known. In normal years its activities are confined to occasional infestations, these often resulting in some of the worst rat damage seen in canefields.

Other Species.

None of the species mentioned below damages sugar cane:

H. chrysogaster may be found in canefields close to water, and particularly in fields in rough country broken by creeks or other running water. This rat seldom interferes with traps or baits used against other species, but it can be a serious pest of poultry on farms where unsuitably protected fowlhouses are located near watercourses, swamps, or lagoons. Of *U. caudimaculatus*, Longman (1916) quotes as follows: "Collett notes that it is said to be not uncommon in hollow trees in the plains, but Krefft stated that the animal frequented rocks more than trees, so that its habitat seems to be variable." The author has trapped this species only in rain forest (sometimes in numbers and in varying stages of growth) and in cane adjacent to it, but its presence in the crop is rare and apparently accidental.

Thetomys gracilicaudatus ultra has never been taken in large numbers, although over a number of years occasional specimens have been regularly recorded. Most of these have come from the drier patches amongst or near *conatus* populations.

Mus musculus has often been taken in numbers in the field during early summer and occasionally at other times. This species may be found in burrows in well-cultivated young plant cane, but its full field dispersal is not known, as the snap traps used for the rats and the methods of using them were not suitable for the taking of this mouse. In farm buildings the house mouse is frequently present in its usual pest role, but no plagues, as occurring in other parts of Australia, and which have been discussed by Murnane (1934), Winterbottom (1920), and many others in topical references, have been reported from Queensland sugar districts.

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